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ABSTRACT

This student guide is for Unit 4, Secondary Circuit, in the Engine Tune-Up Service portion of the Automotive Mechanics Curriculum. It deals with how to test and service the secondary ignition circuit. A companion review exercise book and posttests are available separately as CE 031 215-216. An introduction tells how this unit fits into the total tune-up service, defines new terms, and provides work activities on the introductory information. Seven performance objectives are covered: inspect and replace ignition wires, cap, and rotor; remove, clean, gap, and install spark plugs; analyze engine performance; perform a cylinder power balance test; perform a cylinder leakage test; perform a cylinder compression test; and test and repair transistor ignition system. Each objective is addressed in a separate section that includes these materials: introduction to the performance objective, performance checklist, list of tools and equipment needed to do the work activities for this performance objective, reading list, information sheets, and work activities that give hands-on practice in doing one part of the performance objective. (YLB)

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ENGINE TUNE-UP SERVICE

Unit 4: Secondary Circuit

Student Guide

Automotive Mechanics Curriculum

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CONTENTS

Acknowledgments 1
How to Use This Book 1
Introduction 3

- The Secondary Circuit 5
- Operating Principles 6
- Testing Equipment 7
- New Terms 8
  - *Work Activities* 8

Performance Objective 16: Inspect and Replace Ignition Wires, Cap, and Rotor 11
Introduction 13
Working with Secondary Wires 16
Work Activities 1-2 19
Removing, Testing, and Installing Secondary Wires 19
Work Activities 3-6 24
Replacing Secondary Wires 24
Work Activity 7 29
Removing, Inspecting, and Replacing Distributor Caps and Rotors 30
Work Activities 8-10 35

Performance Objective 17: Remove, Clean, Gap, and Install Spark Plugs 37
Introduction 39
Removing and Inspecting Spark Plugs 42
Work Activities 1-2 47
Cleaning and Gapping Spark Plugs 47
Work Activities 3-4 54
Installing Spark Plugs 54
Work Activities 5-7 61

Performance Objective 18: Analyze Engine Performance . 63
Introduction 65
Procedures for Testing the Secondary Ignition Circuit with Oscilloscope 68

- Overall Secondary Ignition Circuit Tests 69
  - *Work Activities 1-2* 80
- Spark Plug Firing Voltage Tests 80
  - *Work Activity 3* 94
- Distributor Cap and Rotor Tests 95
  - *Work Activity 4* 100

Other Scope Tests Involving the Firing Section 101

- Oily Combustion Chamber 101
- Leaking Exhaust Valve 103

Fuel Starvation 105
Work Activities 5-6 107

Performance Objective 19: Perform a Cylinder Power Balance Test 109
Introduction 111
Procedures for Doing a Cylinder Power Balance Test 114
Work Activity 1 118
Other Tests 119
Work Activities 2-3 121

Performance Objective 20: Perform a Cylinder Leakage Test 123
Introduction 125
Procedures for Doing a Cylinder Leakage Test 128
Work Activities 1-2 136

Performance Objective 21: Perform a Cylinder Compression Test 137
Introduction 139
Procedures for Doing a Cylinder Compression Test 142
Work Activities 1-2 148

Performance Objective 22: Test and Repair Transistor Ignition System 149
Introduction 151
Transistor Ignition Systems 154
Work Activities 1-2 161
Scope Patterns and Tests 161
Work Activities 3-4 171
Detailed Component Tests 171
Chrysler Electronic Ignition System 173
Work Activities 5-6 182
Ford Solid-State Ignition System 182
Work Activities 7-8 197
General Motors High-Energy Ignition System 197
Work Activity 9 203
Component Replacement 204
Work Activities 10-14 209

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HOW TO USE THIS BOOK

As you work through this Student Guide, you'll find directions about when to do certain activities and when to use the Review Exercise Book. Be sure to follow these directions carefully since they lead you step by step to the completion of a performance objective.

Performance Objectives

The performance objectives (abbreviated P.O.) in this Student Guide are statements of what you'll need to do on the job. All the materials in the Student Guide and in the Review Exercise Book are carefully designed to help you do well on performance objectives. So be sure to complete all the activities and try to do well on each activity.

After you have finished the activities for a performance objective, your instructor will test you to see whether you have mastered the necessary skills. A performance checklist will be used to check your work. Each performance objective introduction includes a copy of the checklist. Be sure to read it so that you'll know exactly what you'll be tested on.

A list of tools and equipment that you will need is also provided in the introduction for each objective. If you want more information about a performance objective, be sure to refer to the reading list in that introduction.

Work Activities

You'll need to check with your instructor before and after doing any work activity. Automotive mechanics is a hazardous trade. That's why it's important for you and your instructor to be sure that you do the work activities safely. Each work activity gives you "hands-on" practice in doing one part of a performance objective. If you do each work activity as required in the Student Guide, you'll find it easier to do the complete performance objective later on. Never hesitate to ask your instructor about something you're unsure of in a work activity.

Review Exercise Book

As you work through this Student Guide, you will frequently be directed to complete a pretest or an exercise in your Review Exercise Book. Before you begin the first pretest, read the introduction at the front of the Review Exercise Book. The introduction gives you information about how to use the book so that you'll get the most out of it.

Pretest

Before you go any further, ask your instructor whether you can take the first pretest for Unit 4. The pretest will let you know what to look for in these materials. If you do well on the pretest, your instructor may let you skip some of the study material in the Student Guide.

Your instructor will let you know when to begin studying the materials in this Student Guide.

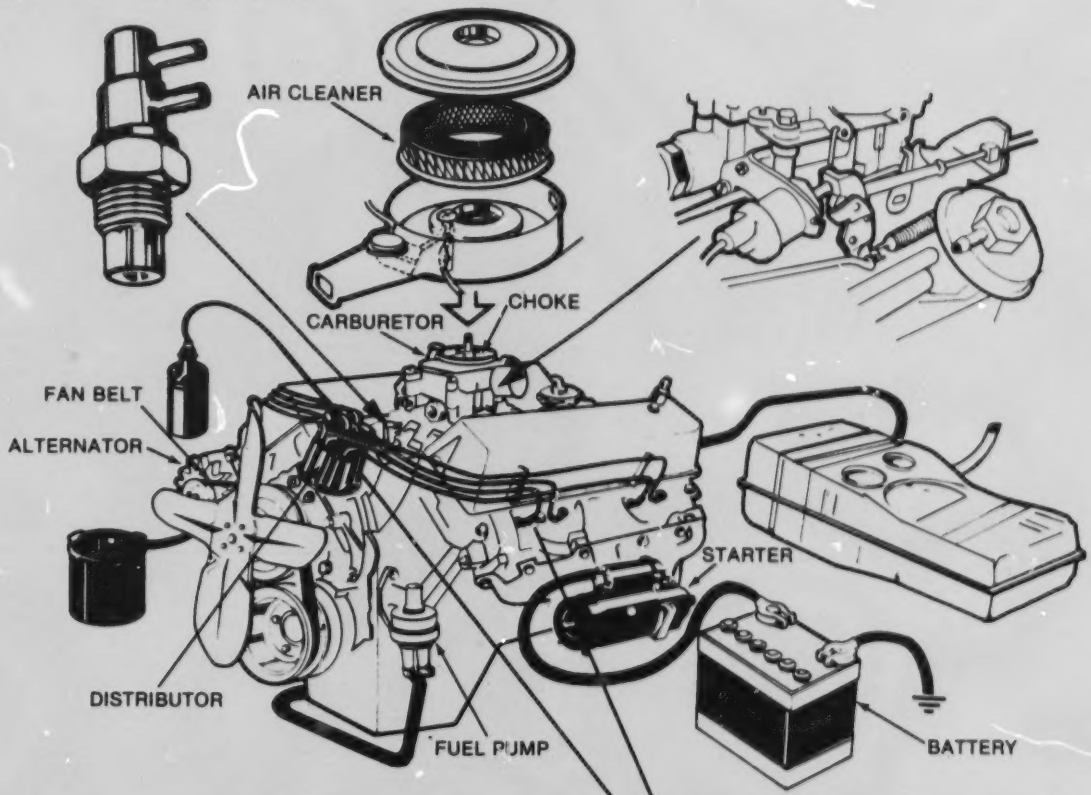
Good luck!

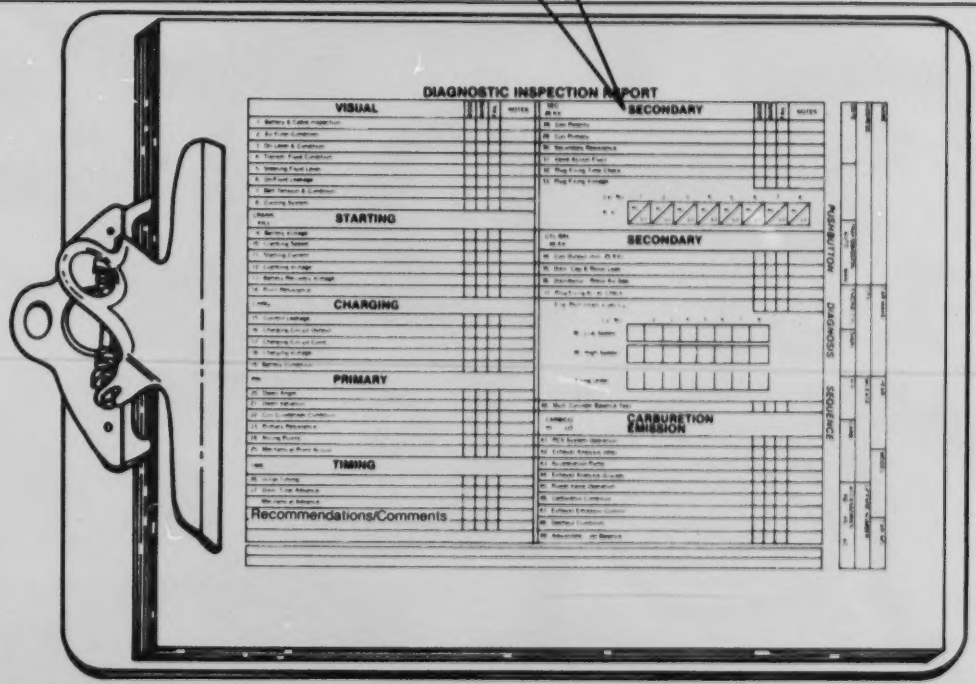
INTRODUCTION

In this section of the Student Guide, you'll learn about the secondary ignition circuit and how to identify the parts and wiring that make up the circuit.

Notice that testing and servicing the secondary ignition circuit is the next step in doing the total tune-up service (see figure 1-1). Following the tests in Unit 4, you'll be doing the adjustments, repairs, and parts replacements, as required, for the secondary circuit.

Figure 1-1 Secondary Circuit





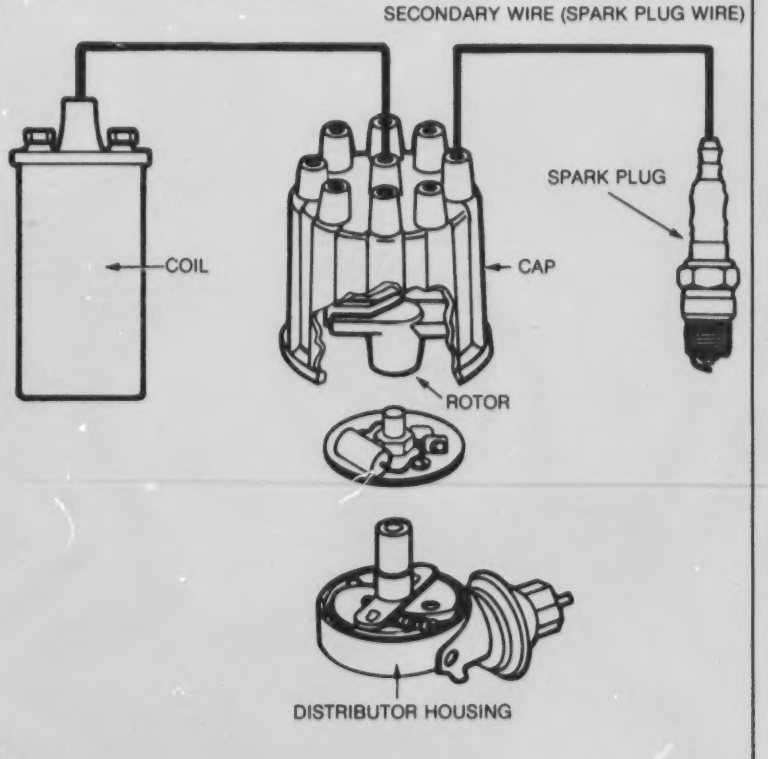
The Secondary Circuit

The instructional material in Unit 4 covers the circuit of the vehicle ignition system called the ***secondary circuit.*** The secondary circuit is the high-voltage part of the ignition system. It carries approximately 25,000 volts of stepped-up voltage from the coil to the spark plugs in order to fire the air-fuel mixture in the engine cylinders. The performance objectives for Unit 4 consist of a description of the secondary circuit—its parts and connecting wires— followed by the various tests, services, repairs, and adjustments you will need to know about to work on this part of the ignition system.

Because approximately 90 percent of all engine-operating malfunctions relate to ignition problems, it is important that you cover each learning sequence of the secondary circuit performance objectives carefully and thoroughly.

The secondary circuit carries the high-voltage charge from the coil to the distributor cap, the rotor, and the spark plugs in order to fire the air-fuel mixture in the engine cylinders.

Figure 1-2 Components of the Secondary Circuit



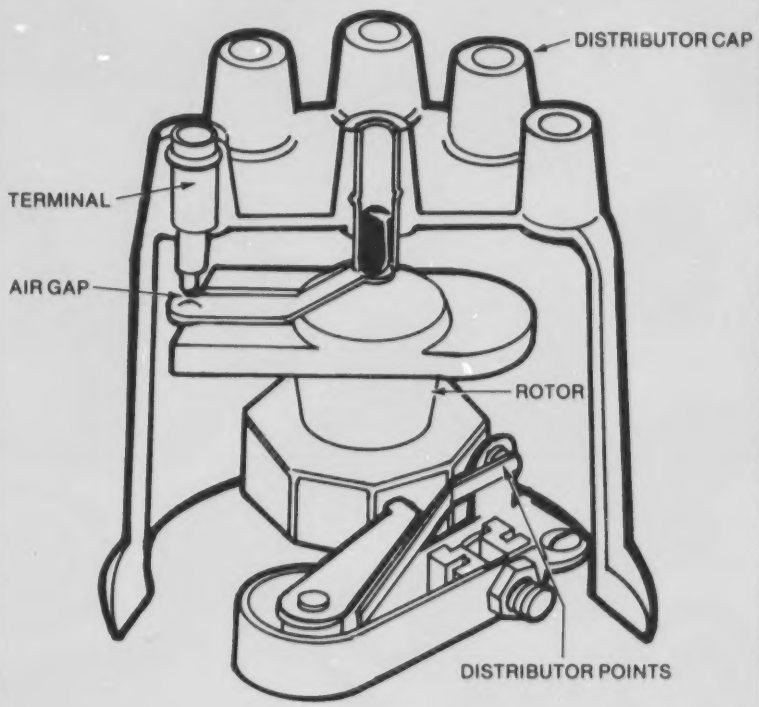
The secondary circuit is made up of the following parts (see figure 1-2):

- The ***ignition coil*** is the key part in any ignition system. It is a step-up transformer that steps up the low voltage (12 volts) to approximately 25,000 volts.
- The ***distributor***, located in the engine, distributes high-voltage charges to the spark plugs in the correct engine firing order. It also delivers the spark to the spark plugs at the right times (according to engine speeds and loads).
- The ***distributor cap*** is the cover at the top of the distributor that encloses the rotor, contact points, and condenser. It consists of towers on the outside that contain the high-tension lead connections. The center tower contains the lead connection for the coil, and there is one tower for the lead connections for each spark plug. On the inside, there are terminals for each high-tension lead.
- The ***rotor*** is located on the distributor shaft. It directs the high-voltage charges coming from the coil to the proper spark plug high tension lead in the distributor cap.
- The ***high-tension leads or cables*** are the conductors of the secondary circuit through which electrical current flows. They are the coil high-tension cable and the spark plug cables.
- The ***spark plugs*** are the components that fire the secondary ignition high voltage in the engine combustion chambers. Their function is to ignite the air-fuel mixture efficiently during all operating ranges of the engine.

Operating Principles

When the contact points open the primary circuit, they allow the coil to discharge the built-up, high-voltage current into the secondary circuit. The high-voltage current travels from the center tower of the coil to the center tower of the distributor cap by way of the coil high-tension cable. From there, the current is passed along by the rotor across an air gap to the spark plug high-tension cables in the distributor cap (see figure 1-3).

Figure 1-3 Distributor Components



The rotor driven by the distributor shaft directs the electrical current to the proper spark plug high-tension cable and the spark plug at the right time. Also, as the rotor rotates past each terminal, the electric charge is delivered to the spark plug and the engine cylinder in a staggered firing order determined by the manufacturer. The spark plug cables are arranged in the distributor cap by the firing sequence that the manufacturer has designed for the engine. This is called *firing order.*

Note that transistor or electronic ignition systems have the same secondary ignition circuit components as the conventional secondary ignition circuit; so they operate in the same way.

Testing Equipment

You'll be using various kinds of testing equipment throughout Unit 4. The equipment will be described more fully when you need to use it to perform the work activities for the secondary circuit. Here is a short description of each piece of equipment.

- A ***spark plug feeler gauge*** is a set of round, metal wires of varying diameters (thicknesses). These wires are used to measure the clearance between the spark plug electrodes. The thickness of each wire is given in thousandths of an inch (.000") so that the air gap between the electrodes can be measured accurately.
- A ***torque wrench*** is a special wrench used to tighten spark plugs as specified by the manufacturer. Measurement specifications for a torque wrench are given in either foot-pounds or inch-pounds of tightness.
- A ***cylinder leakage tester*** is designed to locate compression losses in a cylinder by forcing air into the cylinder and measuring the amount (percentage) of air leakage.
- A ***compression gauge*** is a tester designed to locate compression losses in a cylinder by measuring cylinder compression pressures. Measurements are given in pounds per square inch (psi).

New Terms

In addition to the terms you became familiar with in the units you just completed, you'll need to know the meanings of two new terms before continuing with Unit 4.

- A ***flashover, or arc-over,*** is the travel of current or high voltage across to another terminal, or to ground, by mistake.
- A ***carbon track*** is a path that allows current to travel across from one terminal to another by mistake. Grease, dirt, or the residue caused by flashover creates this path.

Turn to your Review Exercise Book and complete Exercise 1.

WORK ACTIVITIES

Before doing a work activity, make sure you've learned all the information that comes before it in the Student Guide. If you need a review, read the information on the pages listed in parentheses next to each work activity. Do not begin any of the work activities until you have your instructor's approval. If you're not sure that you can do a work activity, ask your instructor for help.

1. Draw the vehicle's secondary ignition circuit and label all parts and wiring, including the circuit grounds (pages 1-8).

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

2. Look at several vehicle engine secondary circuits and identify the parts and wiring that make up the circuit (pages 1-8).

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

After you have finished this activity, go on to the next section.

PERFORMANCE OBJECTIVE 16

INSPECT AND REPLACE IGNITION WIRES, CAP, AND ROTOR

INTRODUCTION

In this performance objective, you'll learn how to inspect and replace the secondary ignition wires, the distributor cap, and the rotor.

After you have finished all the activities for Performance Objective 16, your instructor will use a checklist like the one that follows to evaluate your work.

Performance Checklist—P.O. 16

Your instructor will provide either a live vehicle or shop engine for this objective. Inspect and replace the ignition wires, distributor cap, and rotor. All the performances below must be accomplished.

Student Performances

1. Visually inspects secondary wires and notes any defects.
2. Removes each secondary wire and tests resistance; records results and reinstalls or replaces as necessary.
3. Visually inspects distributor cap and rotor, and notes any defects.
4. Reinstalls or replaces cap and rotor as necessary.
5. Uses proper tools and equipment.
6. Follows all appropriate safety precautions.
7. Does performance in an acceptable amount of time.

Instructor Ratings

	Acceptable	Not Acceptable	Omit
1.			
2.			
3.			
4.			
5.			
6.			
7.			

SAMPLE

Tools and Equipment

You will need to use the following tools and equipment when you do the work activities for Performance Objective 16. You should already be able to use a basic hand tool set; so no procedures are provided here. The procedures for using special tools and equipment, however, will be provided as you work through the activities in this Student Guide.

Basic Hand Tool Set

Special-Purpose Hand Tools

insulated pliers
wire strippers

Basic Equipment

fender covers
extension light
ohmmeter

Special Equipment

spark plug wire kit

Reading List

The Student Guide has been carefully designed to provide you with only the information you need to know to complete each performance objective. If you would like additional information, however, you may wish to use the references below.

General References

Crouse, William H. ***The Auto Book.*** New York: McGraw-Hill, Inc., 1974, pp. 264-65.

Crouse, William H. ***Automotive Mechanics.*** 7th ed. New York: McGraw-Hill, Inc., 1975, pp. 302, 316.

Ellinger, Herbert E. ***Automechanics.*** 2nd ed. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1977, pp. 226-27.

Stockel, Martin W. ***Auto Service and Repair.*** South Holland, Illinois: The Goodheart-Willcox Co., Inc., 1975, pp. (21-6) - (21-8).

Toboldt, William K. and Johnson, Larry. ***Automotive Encyclopedia.*** South Holland, Illinois: The Goodheart-Willcox Co., Inc., 1975, pp. 434-35.

Special-Purpose Reference

Crouse, William H. *Automotive Electrical Equipment.* 8th ed. New York: McGraw-Hill, Inc., 1976, pp. 182, 214-18.

Personal and Service Safety Practices

Safety When Working around the Secondary Ignition System

Vehicle finish. Always use fender covers when working under the hood. This will keep fenders from getting scratched.

Procedures. Always follow correct procedures and use correct tools when replacing ignition wires. This will prevent damage to the terminal ends as well as crimping or stretching of the wires.

Always wipe the distributor cap and surrounding area clean before removing the cap to prevent dirt from getting inside the distributor.

Safety When Making an Electrical Test

Procedures. Follow the procedures described by the manufacturer of the electrical test equipment. This includes proper care and use of the equipment, as well as proper calibration of the equipment when you first start to use it.

Electrical tests. Never do any electrical tests when you are standing in water or when the vehicle or engine parts are wet. A painful shock may result.

Safety in Work Clothing and Grooming

Hair. Keep hair away from the moving parts of an operating engine. Keep hair under a hat if it is longer than conventional length (over your shirt collar).

Clothing. Avoid wearing loose clothing since it can hang down and get caught in the moving parts of an operating engine. Injury can result. Loose clothing can also catch on engine parts and tear.

Jewelry. Avoid wearing any metal (rings, buckles, wristwatches, necklaces, etc.) that can come in contact with electricity. You can receive a severe burn if the metal you are wearing touches an electrical part. You could also damage the electrical unit.

Figure 16-1 Metallic Secondary Wire

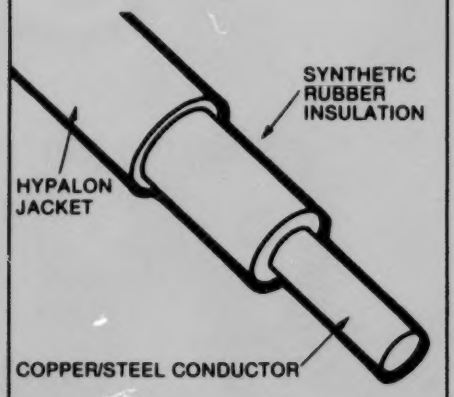


Figure 16-2 Nonmetallic Secondary Wire

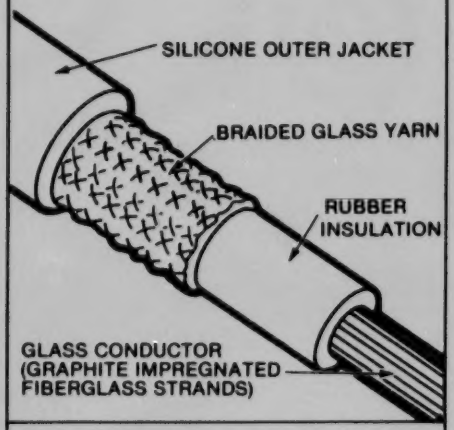
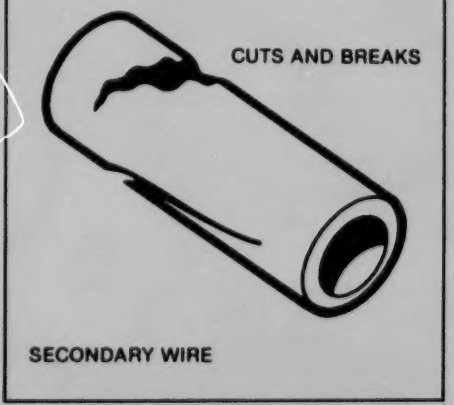


Figure 16-3 A Cut or Broken Wire



Working with Secondary Wires

Secondary wires, also called ignition cables or high-tension cables, must operate under less than ideal conditions. They have to work in very high temperatures (200° F and above); in moisture, oil, grease, and gasoline; and in extremely dry conditions. They also take mechanic abuse.

It is important that they are handled carefully, are properly routed to the spark plugs, and are connected in the proper engine firing order.

There are two kinds of conductors used in secondary wires—metallic (see figure 16-1) and nonmetallic (see figure 16-2). The nonmetallic wire is the only one that is presently used on vehicles. It is the one emphasized in this Student Guide.

For American vehicles since 1960, the conductor, or core, of secondary wires has been made from glass fiber or linen yarn, heavily embedded with carbon particles. The insulating synthetic rubber and its jacket, called a hypalon jacket, protect the yarn from the elements (see figure 16-2).

The conductor in a secondary wire is basically a string, which is easily broken if mishandled.

The nonmetallic secondary cables help to reduce radio noise caused by the ignition system. They also help lengthen the life of the spark plugs.

Defects That May Develop in the Secondary Wires, and Visual Inspections for These Defects

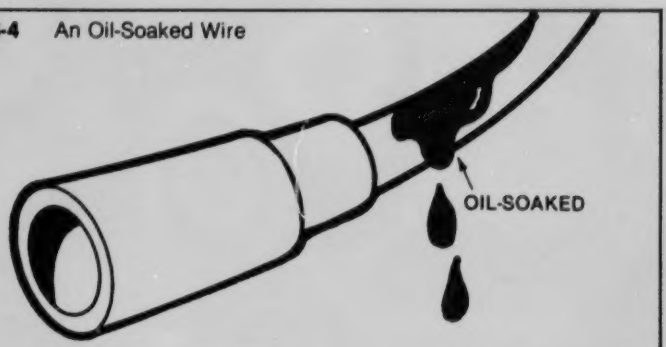
Condition.

- Dry, cracked insulation; cuts and breaks in the wires (see figure 16-3). Wires should be replaced.
- Wires that are oil- or grease-soaked, dirty, or salt-encrusted (see figure 16-4). Wires should be replaced unless they can be cleaned satisfactorily with a damp cloth and a mild detergent.

Always keep wires away from heat and from oily places. Wires must also be kept away from exhaust manifolds.

Improper routing. Secondary wires to the spark plugs should be routed properly to prevent cross-firing. Cross-firing occurs when the spark from one spark plug wire induces a current in the wire lying next to it. It causes the wrong spark plug to fire in the wrong cylinder at the wrong time. Cross-firing happens when the secondary wires are touching each other, particularly those wires that connect to the spark plugs of cylinders that are side by side.

Figure 16-4 An Oil-Soaked Wire



You'll recall in Unit 3 the exercise of locating the #1 cylinder on V-8 engines, 6-cylinder engines, and 4-cylinder engines. To review briefly:

V-8 engines—#1 cylinder is located directly behind the radiator

All General Motors vehicles except Cadillac, all AMC vehicles, and all Chrysler Corporation vehicles—#1 cylinder is located on the left side

Ford, Lincoln, Mercury, and Cadillac—#1 cylinder is located on the right side

Six-cylinder and 4-cylinder engines—#1 cylinder is located directly behind the radiator

You'll also recall how you traced the #1 spark plug wire back to the distributor cap and marked the location of the #1 wire on the distributor cap.

In every vehicle, the firing order of all the cylinders begins with the #1 cylinder or the #1 spark plug. The rotor turns clockwise in some vehicles and counterclockwise in others. As the rotor turns, it determines which cylinder fires next, which fires after that, and so on through the engine-firing sequence.

If the firing order is not correct on an engine, it causes the engine to miss and perform poorly in terms of fuel economy, acceleration, power, and starting. It is a good practice to check the firing order routing of the secondary wires as well as to know what the various engine firing orders are.

- Check the wires to see that they are properly routed through the routing clips (see figure 16-5).
- Wires should not touch each other or run parallel for long distances. If you are unsure about the correct routing of secondary wires, make sure to check the vehicle manufacturer's recommendations.

Figure 16-5 Example of Incorrect Routing

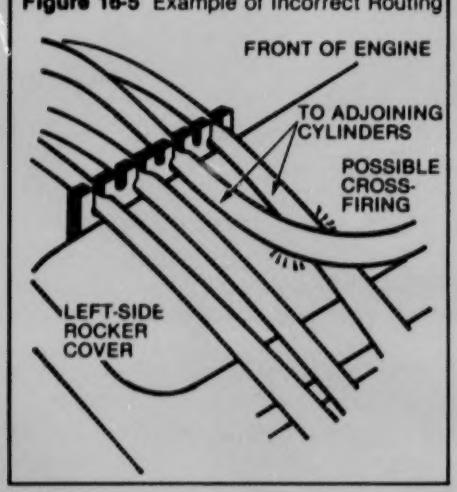


Figure 16-6 Firing Order of a 6-Cylinder Engine

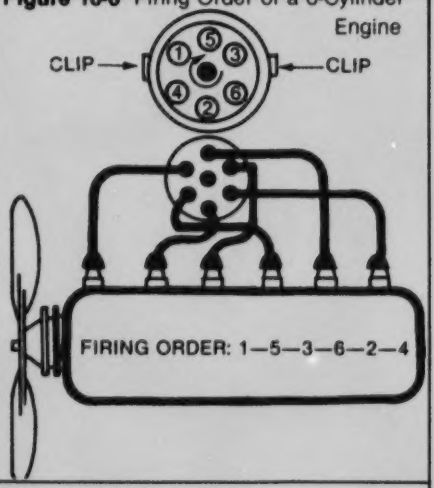


Figure 16-7 Most Common Firing Order of a V-8 Engine

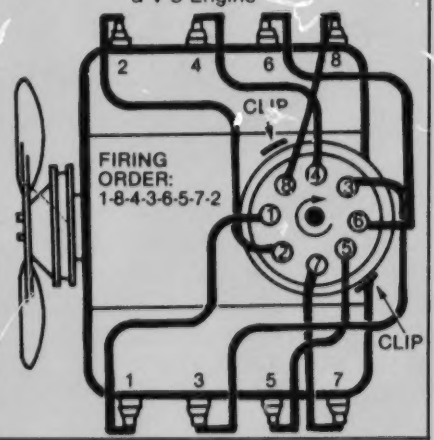
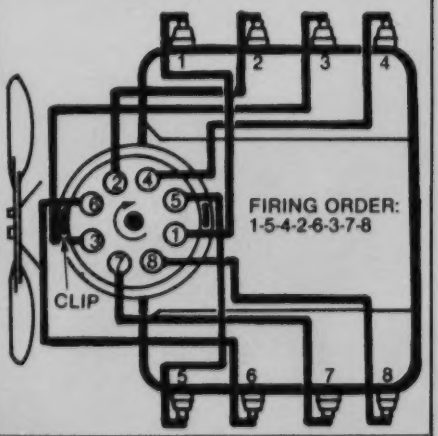


Figure 16-8 Another Firing Order of a V-8 Engine



Incorrect firing order. In order to reduce engine vibration and get a smooth, even flow of power from the engine, the cylinders must fire in the correct sequence. The sequence is determined by the vehicle manufacturer. The firing order, then, is the numerical order in which the cylinders fire the final charge, beginning with the #1 cylinder.

- The firing order of in-line 6-cylinder engines in the U.S. is 1-5-3-6-2-4 (see figure 16-6).

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- The most popular (most common) firing order of a V-8 is 1-8-4-3-6-5-7-2 (see figure 16-7).

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- Another firing order used on a V-8 is 1-5-4-2-6-3-7-8 (see figure 16-8).

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You'll find the firing order for each particular vehicle and engine in your technical service manual. Some will appear in a diagram like the one below. In the diagram, notice the arrow in the center of the distributor cap. The arrow tells you the direction of rotor rotation. Then, going around the cap in the direction of rotor rotation, you'll notice the numbers of the correct firing order. Even the distributor cap hold-down clips are indicated so that you can locate the position of the cap on top of the distributor.

- The firing order of 4-cylinder in-line engines can be either 1-3-4-2 or 1-2-4-3 (see figure 16-9).

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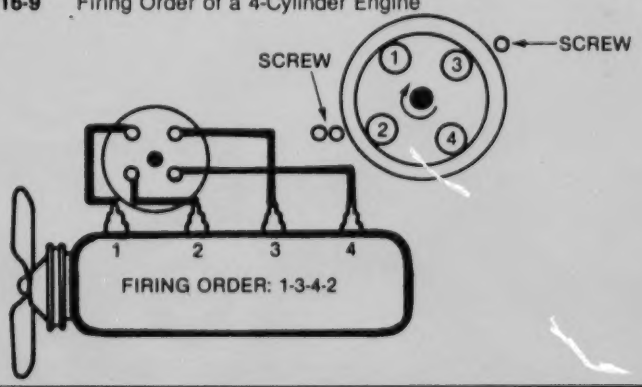
Figure 16-9 Firing Order of a 4-Cylinder Engine



Turn to your Review Exercise Book and complete Exercise 2.

WORK ACTIVITIES

Before doing a work activity, make sure you've learned all the information that comes before it in the Student Guide. If you need a review, read the information on the pages listed in parentheses next to each work activity. Do not begin any of the activities until you have your instructor's approval. If you're not sure that you can do a work activity, ask your instructor for help.

1. Visually inspect the secondary wires for defects (pages 16-19). Write down the defects you find.

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

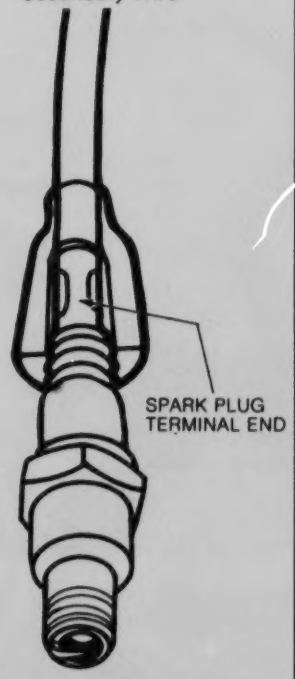
2. Trace the firing orders on several vehicles (pages 16-18). Write them down by vehicle year, make, and model.

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

After you have finished these activities, go on to the next section.

Figure 16-10 Disconnecting a Secondary Wire

Figure 16-11 Straight Terminal End of a Secondary Wire



Removing, Testing, and Installing Secondary Wires

Removing

In this section of the Student Guide, you'll learn how to disconnect and test one secondary wire at a time. Later, you'll learn how to replace the complete set of secondary wires.

STEP 1 Remove the spark plug end of one secondary wire by first twisting the rubberlike boot back and forth. This breaks the seal that the protective boot forms around the top of the spark plug. Be sure you twist the boot and not the wire (see figure 16-10).

STEP 2 Then, gripping the end of the boot, pull or snap the secondary wire straight out, away from the spark plug. A quick pull or snap helps to separate the metal clip from the spark plug terminal.

NOTE: Secondary wire metal clip terminals are shaped either straight, as shown in figure 16-11, or bent at right angles, as shown in figure 16-10. Either way, the rubberlike boot must be twisted first to release its grip on the spark plug.

Figure 16-12 Using Insulated Spark Plug Wires to Disconnect the Terminal

STEP 3 If the engine is hot and the spark plugs are located close to the exhaust manifold, use a pair of insulated pliers to remove the secondary wires. This will keep your hands from getting burned (see figure 16-12).

NOTE: Follow the same removal procedures for each wire. Grip the boot near its top and twist it to break the seal. Be sure you twist the boot and not the wire! Then pull the boot, the wire, and its terminal straight out and away from the spark plug.

STEP 4 Before removing any secondary wires from the distributor cap, place the #1 spark plug wire in its distributor cap terminal. Mark the location of the distributor cap terminal with a piece of chalk.

STEP 5 Then, remove the same secondary wire that you disconnected at the spark plug (see figure 16-13). Again, break loose the rubberlike nipple from the distributor cap tower. To do this, peel the nipple back from around the tower of the distributor cap.

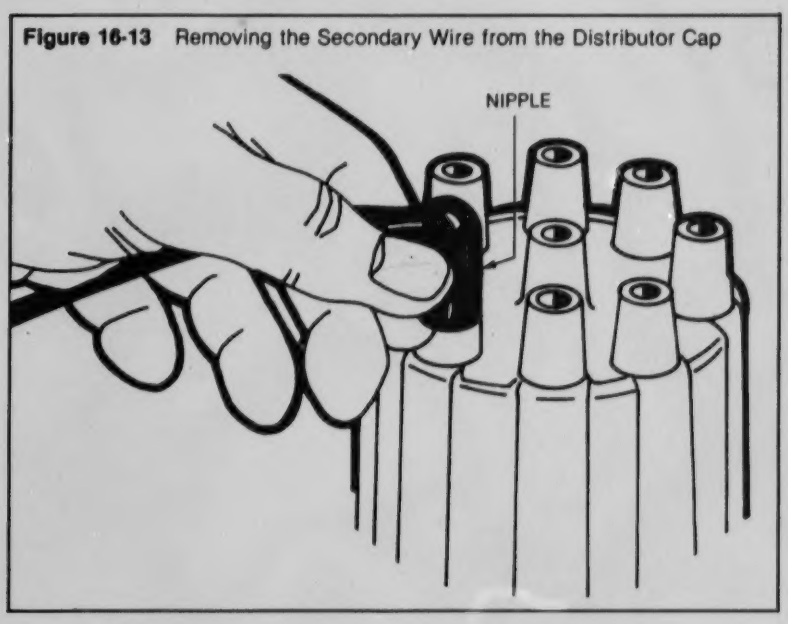


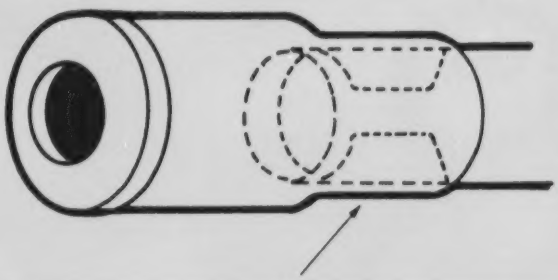
Figure 16-13 Removing the Secondary Wire from the Distributor Cap

STEP 6 Then, grip the upper part of the nipple and the wire. Pull the secondary wire straight out, away from the distributor cap.

Testing

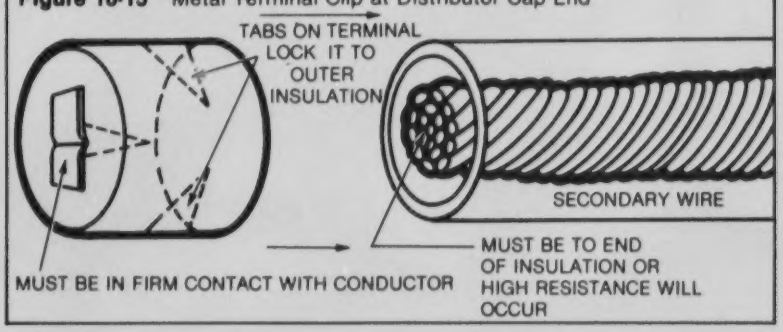
Once the secondary wire is free from the distributor cap and the spark plug, check the metal terminal clips at both ends for tightness on the wire, corrosion, and breakage (see figure 16-14).

Figure 16-14 Metal Terminal Clip at Spark Plug End



The secondary wire end that fits into the distributor cap is also a metal clip. These clips come in many shapes and arrangements. You'll notice that the clip in figure 16-15 is designed to fit over the end of the wire squarely. The clip is locked to the outer insulation of the wire by locking metal tabs. At the center of the clip, a center metal tab fits firmly into the conductor and makes a good electrical connection.

Figure 16-15 Metal Terminal Clip at Distributor Cap End


TABS ON TERMINAL LOCK IT TO OUTER INSULATION
SECONDARY WIRE
MUST BE TO END OF INSULATION OR HIGH RESISTANCE WILL OCCUR
MUST BE IN FIRM CONTACT WITH CONDUCTOR

If a clip is broken or loose, repair it by using a stripping and crimping tool, or replace it by installing a new clip.

To install a new metal clip:

- Fit the clip onto the end of the wire, pushing the center metal tab of the clip into the center of the wire. Be sure the clip is pushed all the way down on the wire.
- Squeeze the metal clips and the tabs firmly to the wire.

Figure 16-16 Cleaning the Distributor Cap Towers

If a clip is corroded at the distributor cap end, clean off the corrosion with a knife or emery cloth. You'll also have to clean the corrosion from the distributor cap tower.

To clean corrosion from the distributor cap tower, use a small, round, stiff wire brush (see figure 16-16). This brush is called a distributor tower cleaner brush. After you scrape away the corrosion, use an air hose to blow the particles out of the tower.

If the terminals are in good condition, use an ohmmeter to test the secondary wire for high resistance.

Before you test the secondary wire, refer to the "high-tension wire resistance" specifications in your technical service manual. They will look something like this:

Resistance (ohms)

Wire Length	Minimum	Maximum
0-15"	3,000	10,000
15-25"	4,000	15,000
25-35"	6,000	20,000
above 35"	—	25,000

You'll notice that the amount of resistance for secondary wires is based upon the length of the wire. To read the chart, a wire length of 0-15 inches long should have minimum resistance of 3,000 ohms. This same wire length is allowed a maximum of 10,000 ohms.

To test:

STEP 1 Set the VOLT and OHM selector to X1000.

STEP 2 Calibrate the ohmmeter.

STEP 3 Connect one tester lead to the spark plug end of the wire (see figure 16-17).

STEP 4 Touch the other tester lead to the terminal on the distributor cap end of the wire.

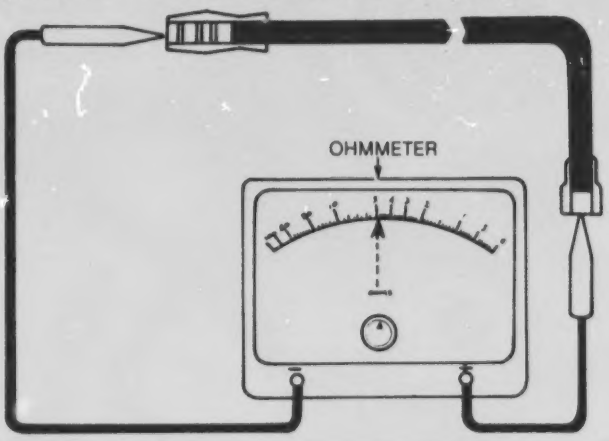
STEP 5 Read the meter.

GOOD Resistance is within specification or, if not specified, is less than 20,000 ohms.

BAD Resistance that is not within specifications indicates a broken or otherwise damaged wire. It needs to be replaced.

It is a good idea to twist the wire while you are watching the reading on the ohmmeter. If the needle fluctuates, replace the wire, because the fluctuation indicates a broken or partially separated conductor within the wire.

Figure 16-17 Connections for Testing a Secondary Wire


OHMMETER
HIGH RESISTANCE
1. CHECK FOR BREAKS IN CONTACT AT TERMINALS; ALSO CHECK FOR BROKEN CONDUCTOR.
2. MEASURE RESISTANCE.

Now, reinstall the tested secondary wire and proceed to test each one of the others in turn, including the high-tension coil wire.Later in this unit, you will learn how to test secondary wires by using a scope.

Installing

In reinstalling the secondary wires onto their terminals following the testing of each wire, there are a few points you'll want to remember.

- **Spark plug end.** Insert the terminal metal clip and boot over the spark plug. Grip the top part of the boot and wire, and push in to seat the terminal firmly onto the spark plug. Sometimes you'll hear a snap when the terminal attaches to the spark plug, indicating that a good, tight connection has been made.

NOTE: Be sure the boot fits down as far as it can around the top of the spark plug.

- **Distributor cap end.** Insert the terminal metal clip into the distributor cap. When installing, pinch the top of the nipple as you push the wire into the cap. This will expel any air pressure buildup in the cap tower and let you seat the terminal end down in the distributor cap tower. Sometimes you'll hear a snap when the wire terminal seats into the cap. This indicates that a good, tight connection has been made. Then, push the rubberlike nipple all the way down around the cap tower.

Turn to your Review Exercise Book and complete Exercise 3.

WORK ACTIVITY

Before doing a work activity, make sure you've learned all the information that comes before it in the Student Guide. If you need a review, read the information on the pages listed in parentheses next to each work activity. Do not begin any of the work activities until you have your instructor's approval. If you're not sure that you can do a work activity, ask your instructor for help.

3. Mark the location of the #1 spark plug wire on the distributor cap (pages 19-20).

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

4. Disconnect the secondary wire from the spark plug and the distributor cap (pages 19-20).

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

5. With an ohmmeter, test each secondary wire for the amount of resistance. Compare results with the manufacturer's specifications (pages 21-23).

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

6. Install the secondary wires at the spark plugs and the distributor cap (pages 22-23).

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

After you have finished these activities, go on to the next section.

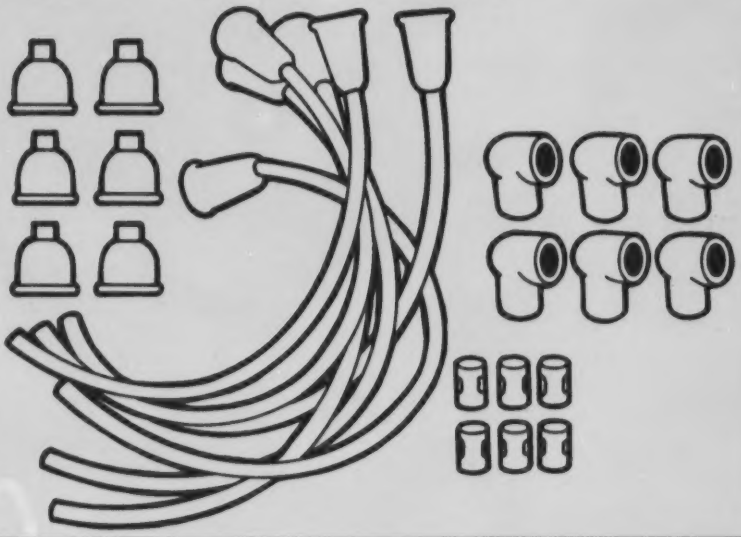
Replacing Secondary Wires

You have learned to remove and test secondary wires, one at a time. You first marked the position of the #1 spark plug wire on the distributor cap tower. Then you worked around the cap, removing and testing each wire as you went to avoid mixing up the firing order of the engine.

This is the best way to work with secondary wires. You should continue to follow this practice when removing, testing, or replacing the secondary wires.

Secondary wire sets. Secondary wires are available in two forms. One form is the factory ready-made set that has all the wires precut to the proper length to fit each cylinder (see figure 16-18). When installing secondary wires, you must match up the length of the old wire with the new to ensure that you are using wire that is the correct length for a particular cylinder.

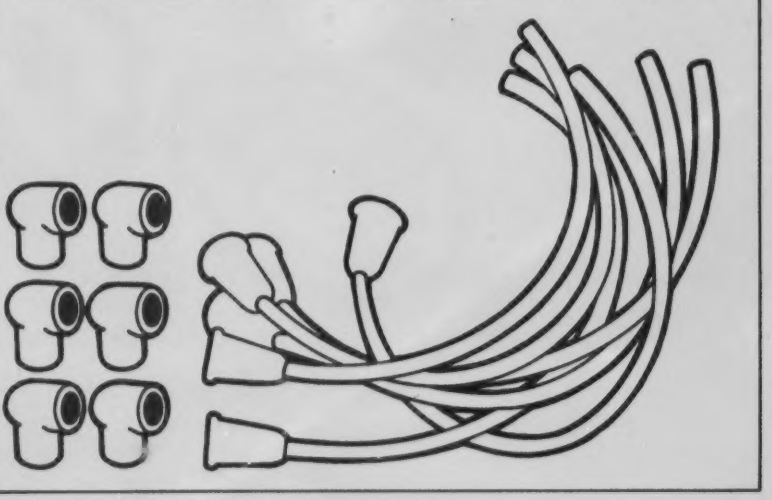
Figure 16-18 Ready-Made Set of Secondary Wires



The ready-made set furnishes the metal clips and nipples for the distributor cap end of the wires. You'll need a wire-stripping and crimping tool to install the clips at the ends of the wires.

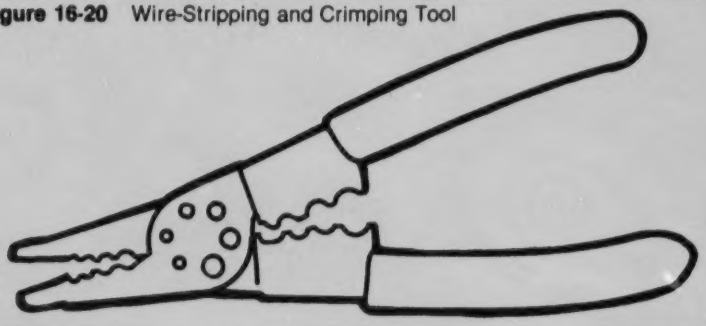
The other form in which secondary wires are available is a set of wires of varying lengths, not cut to fit any particular engine. You must cut the wires and fit them individually to each cylinder or spark plug. The metal clips, boots, and nipples for both ends of the wires are furnished with the set (see figure 16-19).

Figure 16-19 Secondary Wires That Must Be Cut to Fit a Particular Engine



Depending on the type of wire you use and the type of clip on the distributor end of the wire, you'll probably need a wire-stripping and crimping tool (see figure 16-20).

Figure 16-20 Wire-Stripping and Crimping Tool



Routing Secondary Wires

STEP 1 To cut the wire to the proper length, start with the #1 spark plug wire of the firing order. (Mark the distributor cap if you haven't already done so.) Remove the wire from the engine.

STEP 2 Lay the old wire alongside the new one; cut the new wire to equal the length of the old one. Even with a ready-made set of wires, you'll want to match the wire lengths to be sure you have the right set for the cylinder you're working on.

STEP 3 Route the new wire on the engine in the place of the old. In some instances, the wire must be routed through small, tight passages. Do not force, yank, or pull the wire because this will damage it.

STEP 4 Next, set the wire into the clips, or "looms," that support the wire and keep it apart from the other wires.

CAUTION: Always make sure that the wires are as short as possible. Do not make any sharp bends in them or let them come into contact with ***heated, vibrating,*** or ***moving parts.***

Some wiring arrangements look like these below.

Figure 16-21 Wiring from Passenger's Side of Engine Compartment

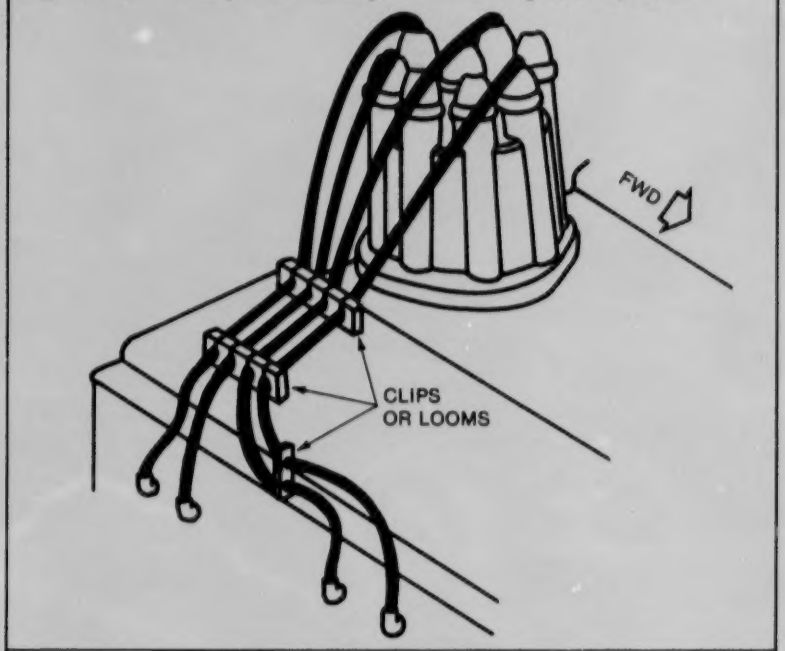
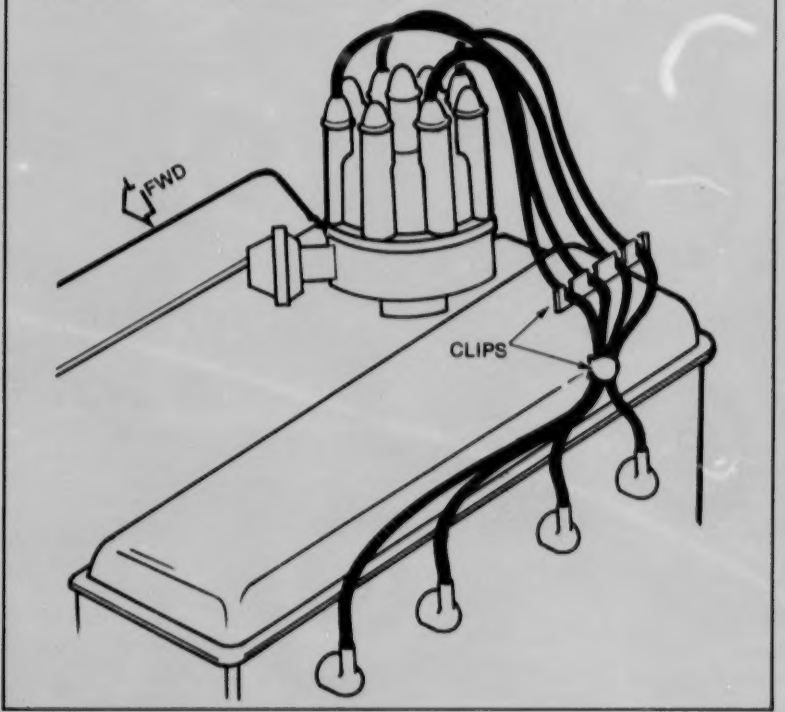


Figure 16-22 Wiring from Driver's Side of Engine Compartment



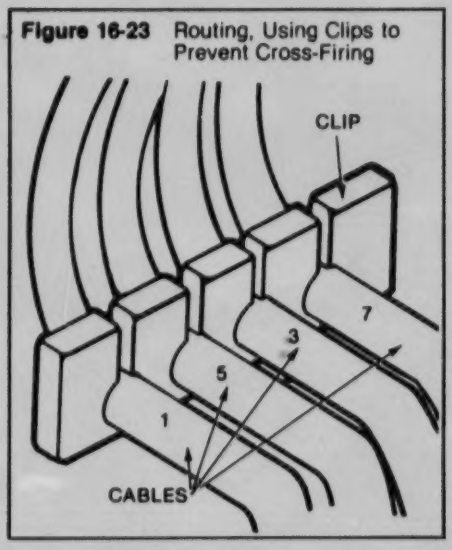
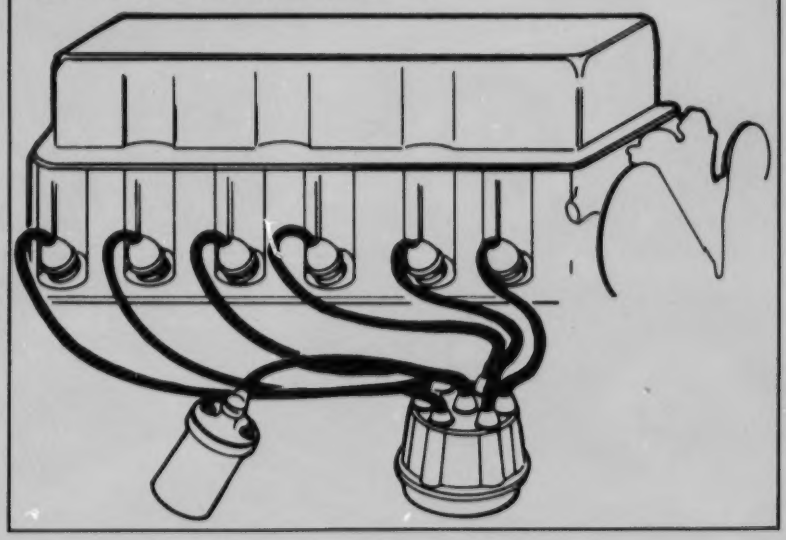


Figure 16-23 Routing, Using Clips to Prevent Cross-Firing

In figure 16-23, notice how the wires on cylinders #5 and #7 are separated by wire #3 to prevent cross-firing.

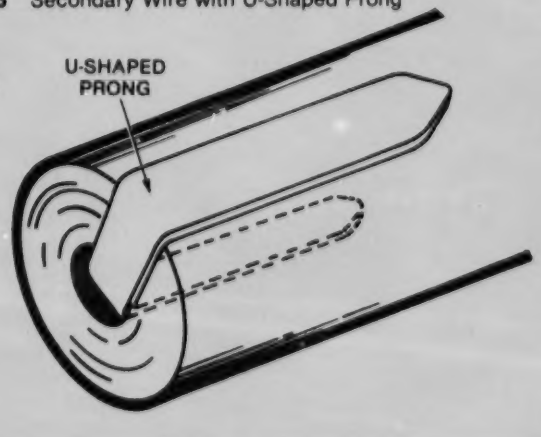
STEP 5 Install the boots and nipples on the appropriate ends of the wire. Then, install the metal clips. A wire-stripping and crimping tool is used to squeeze the clips tightly onto the wire ends.

Figure 16-24 Wiring on a 6-Cylinder Engine



Some wire sets use a simple U-shaped prong, one side of which is inserted into the center of the wire (see figure 16-25). The other side lies flat along the outside of the wire. Then, a metal clip is placed inside the distributor tower and the wire is pushed into the metal clip.

Figure 16-25 Secondary Wire with U-Shaped Prong



STEP 6 Install the wire terminals to the spark plug and the distributor cap as you did before.

STEP 7 Install the remaining secondary wires, including the coil wire, in the same way until all of the secondary wires have been replaced.

Making an operational check. First, make a final inspection of your work. Check the wire connections for tightness. Be sure the boots and nipples are properly covering the connections. Check the proper location of each wire in its routing and, of course, check each wire against the firing order for the engine.

Then start the engine. Notice whether the engine runs smoothly or misses. Accelerate and decelerate a few times. While the engine is operating, visually inspect the wires and look for sparks jumping from the wires to ground or to each other. Correct any defects that you find.

Secondary wires should also be checked by using a scope. Later in this unit you will learn how to do this.

Turn to your Review Exercise Book and complete Exercise 4.

WORK ACTIVITY

Before doing a work activity, make sure you've learned all the information that comes before it in the Student Guide. If you need a review, read the information on the pages listed in parentheses next to the work activity. Do not begin the work activity until you have your instructor's approval. If you're not sure that you can do the work activity, ask your instructor for help.

7. Replace the secondary wires on an engine (pages 24-28).

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

After you have finished this activity, go on to the next section.

Removing, Inspecting, and Replacing Distributor Caps and Rotors

Removing the Distributor Cap

STEP 1 Remove the distributor cap by unsnapping the spring arms. If it is the window-type cap, use a screwdriver to press the latch down (see figure 16-26). When the latch is down, turn it one-quarter of a turn to release it from the distributor.

STEP 2 Turn the distributor cap upward and inspect it.

NOTE: Be sure to clean any excess dirt from around the cap before removing it.

Removing the Rotor

STEP 1 Remove the rotor by working it up off the distributor shaft. Some rotors are attached to the advance mechanism by screws.

STEP 2 Inspect the rotor.

Visual Inspection for Defects That May Develop in the Distributor Cap and Rotor

The flow of high-voltage, secondary current from the coil through the cap and rotor to the spark plug can in time cause terminals to erode or to burn out, flashovers between terminals, and other kinds of damage. This damage, in turn, can cause engines to miss and can lower engine performance. Figure 16-27 shows the flow of secondary current through the terminals and the connections in the distributor cap and rotor.

Figure 16-26 Removing a Window-Type Distributor Cap

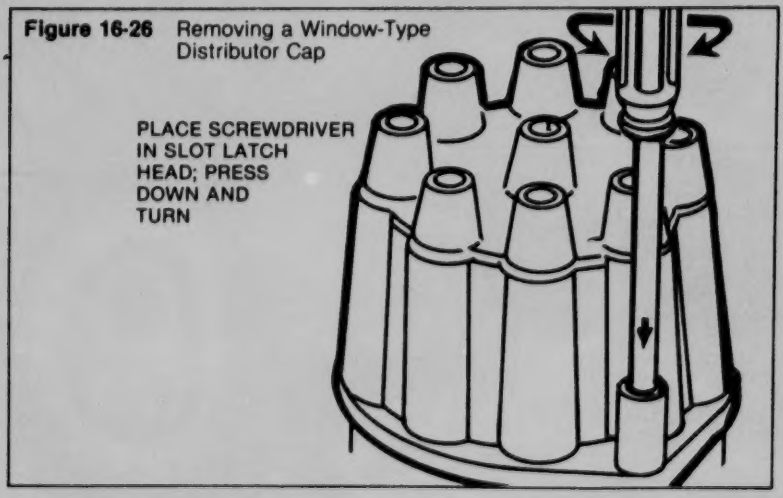


Figure 16-27 Flow of Current through Terminals

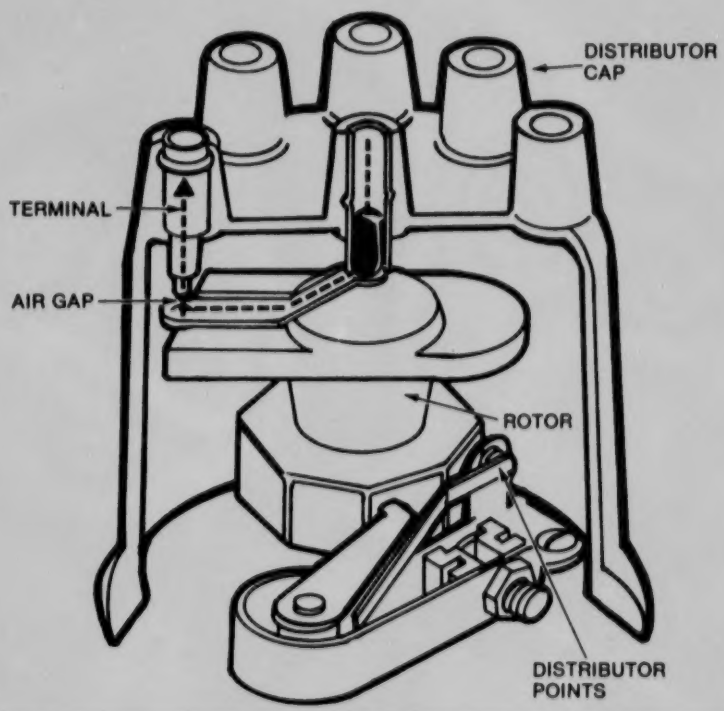
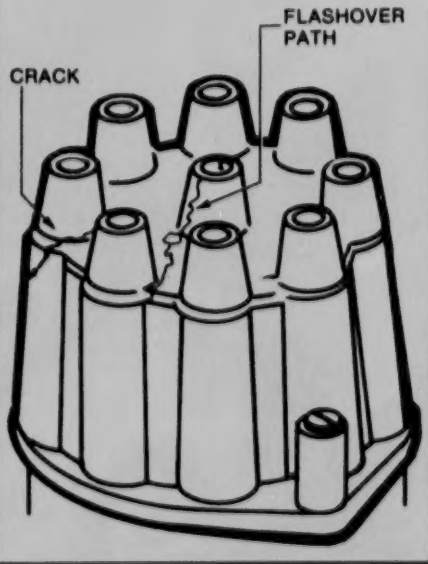


Figure 16-28 Distributor Cap with Crack and Flashover Path



STEP 1 Check the distributor cap.

- A cap that is greasy or dirty on the outside creates a path that can allow the high-voltage current to escape. The current may travel to another terminal or to ground. Flashover especially happens when the wire connections are loose. Also check the distributor cap for cracks (see figure 16-28).
- Then, check the inside of the distributor cap for carbon tracking, which is caused by flashover from one terminal to another (see figure 16-29). Grease and dirt inside the cap can also cause flashover to another terminal. In both cases, the cap should be replaced because erosion and damage to the cap has started.
- If the rotor contact at the center of the distributor cap is burned away, the cap should be replaced (see figure 16-30).

Figure 16-29 Carbon-Tracking Inside of Distributor Cap

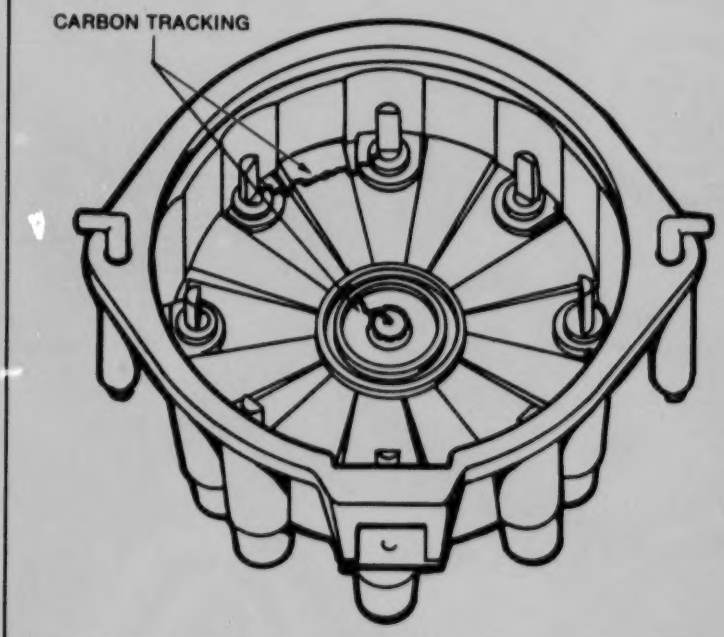
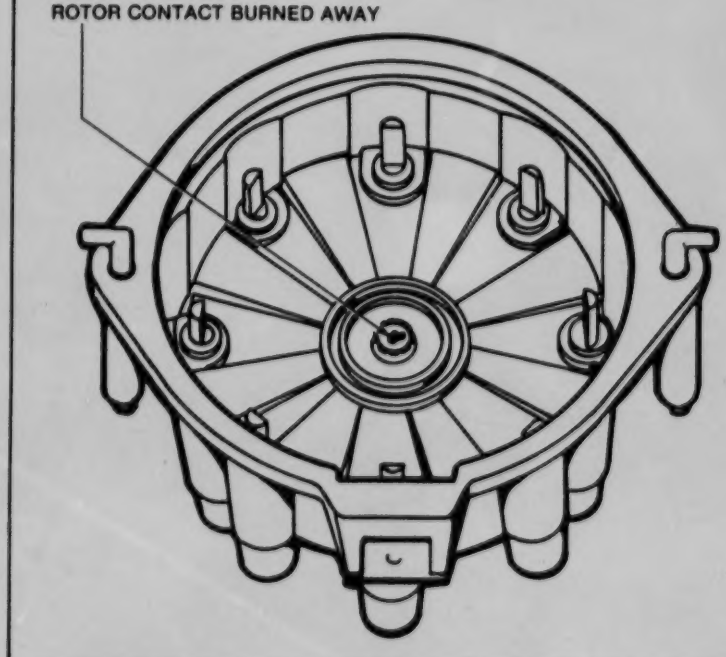
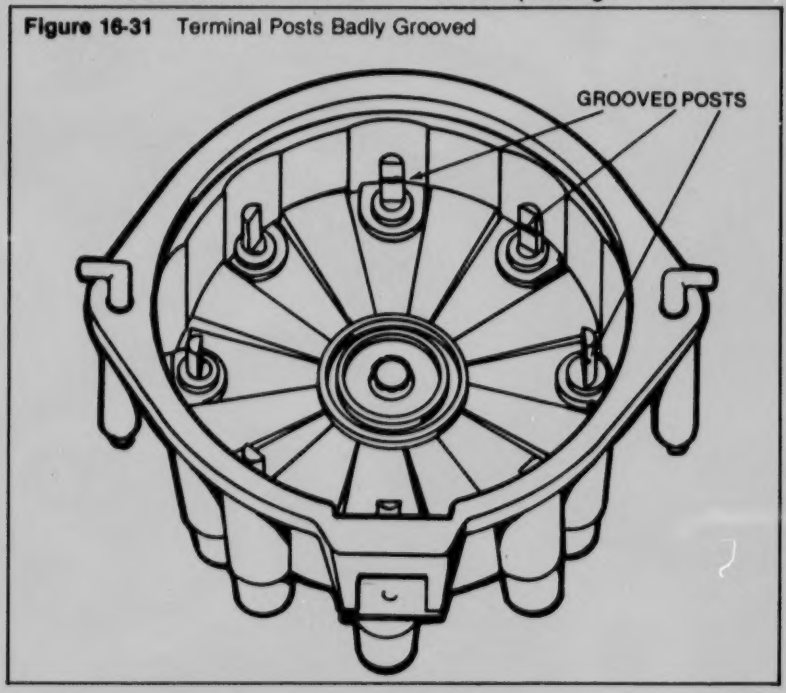


Figure 16-30 Rotor Contact Burned Away



- If the terminal posts are burned or badly grooved, the cap should be replaced. Mild scaling, caused by the spark leaping from the rotor tip to the terminal post, can be scratched off with a knife blade (see figure 16-31).

Figure 16-31 Terminal Posts Badly Grooved



STEP 2 Check the rotor.

- Check the resistance rod to see if it is broken or burned out. Check the contact spring to see if it is broken or excessively worn or grooved (see figure 16-32).
- Inspect the rotor for excessive burning on the tip (see figure 16-33).

Figure 16-32 Items to Check on the Rotor

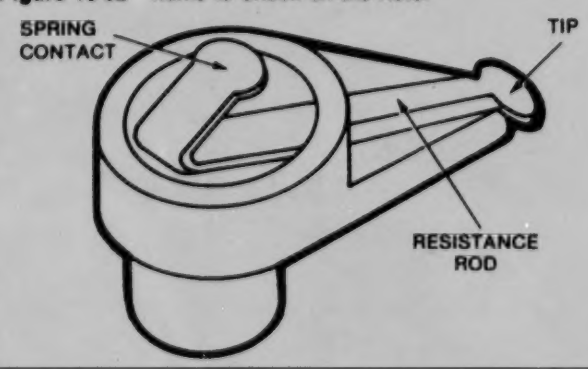
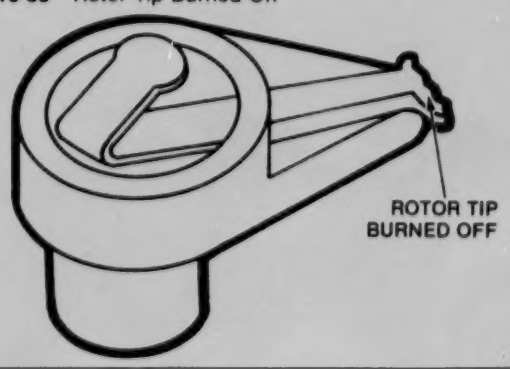


Figure 16-33 Rotor Tip Burned Off



- If one or more of these defects are found, the rotor should be replaced.

NOTE: Whenever you replace the distributor cap, replace the rotor at the same time.

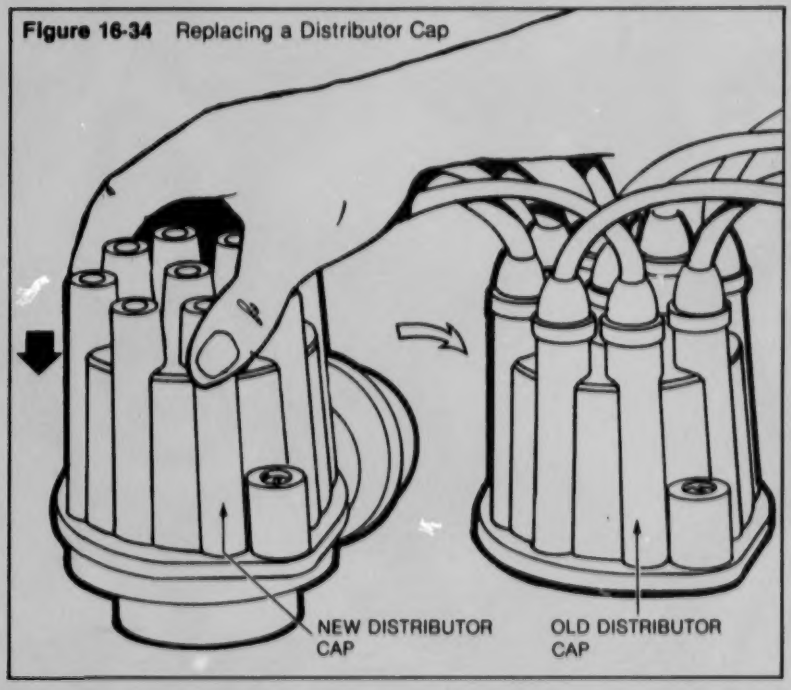
Replacing the Rotor and Distributor Cap

STEP 1 The rotor is installed in the reverse order of the removal procedures. Be sure the rotor groove, flats, or tabs match the distributor shaft groove or the advance mechanism openings.

STEP 2 Mark the location of the #1 spark plug wire on the old distributor cap if you haven't already done so.

STEP 3 Remove the old cap from the distributor and move it to one side. Do not remove the secondary wires at this time (see figure 16-34).

Figure 16-34 Replacing a Distributor Cap



STEP 4 Install the new distributor cap onto the distributor. Be sure the distributor cap is centered over the rotor and fits squarely down on the distributor.

STEP 5 Transfer one secondary wire at a time to the new distributor cap, starting with the #1 spark plug wire.

- If you'll follow this procedure, you won't mix up the firing order.

Making an Operational Check

First, make a final inspection of your work. Check the wire connections for tightness. Be sure the rubberlike nipples are fitted properly down and around the distributor cap terminals. Check the wires against the firing order for the engine. Then, start the engine.

Notice whether the engine runs smoothly or whether it misses. Accelerate and decelerate a few times. While the engine is operating, visually inspect the wires and cap and look for sparks jumping from the terminals or from one terminal to another. Correct any defects that you find.

Distributor caps and rotors can also be checked by using a scope. You will learn how to do this later in this unit.

Turn to your Review Exercise Book and complete Exercise 5.

WORK ACTIVITIES

Before doing a work activity, make sure you've learned all the information that comes before it in the Student Guide. If you need a review, read the information on the pages listed in parentheses next to each work activity. Do not begin any of the work activities until you have your instructor's approval. If you're not sure that you can do a work activity, ask your instructor for help.

8. Remove the distributor cap and rotor (page 30).

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

9. Visually inspect the distributor cap and the rotor for defects. Write down the defects you find (pages 30-33).

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

10. Install a new rotor and a new distributor cap (pages 34-35).

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

When you have finished these activities, ask your instructor to return your pretest on Performance Objective 16. Complete the questions that you missed or were unable to answer the first time you took the pretest. Check your answers with your instructor when you finish. Your instructor will tell you if you are ready to be checked off on the performance checklist, or if you need to correct some of your answers first.

If you are told by your instructor that you are ready for the performance checklist, carefully tear the checklist out of your Review Exercise Book and give it to your instructor.

PERFORMANCE OBJECTIVE 17

REMOVE, CLEAN, GAP, AND INSTALL SPARK PLUGS

INTRODUCTION

In this performance objective you'll read about ways to remove, clean, gap, and install spark plugs.

You may find it helpful to review Performance Objective 16, where you'll find information on removing spark plug wires and on engine firing orders. That information will help you remove and reinstall spark plug wires correctly, and attach the wires to the correct spark plug if the wires become mixed up.

After you have finished all the activities for Performance Objective 17, your instructor will use a checklist like the one that follows to evaluate your work.

Performance Checklist—P.O. 17

Your instructor will provide either a live vehicle or a live engine for this objective. Remove, clean, gap, and install a set of spark plugs. All the performances below must be accomplished.

Student Performances

1. Removes spark plugs in order from the engine.
2. Examines spark plugs and records any defects.
3. Cleans and files spark plugs, or replaces as necessary.
4. Adjusts spark plug gaps to specifications.
5. Installs spark plugs in engine and torques to specifications.
6. Performs operational check of spark plug performance.
7. Uses correct tools and equipment.
8. Follows all appropriate safety precautions.
9. Does performance in an acceptable amount of time.

Instructor Ratings

Acceptable	Not Acceptable	Omit

SAMPLE

Tools and Equipment

You will need to use the following tools and equipment when you do the work activities for Performance Objective 17. You should already be able to use a basic hand tool set, so no procedures are provided here. The procedures for using special tools and equipment, however, will be provided as you work through the activities in this Student Guide.

Basic Hand Tool Set

Special-Purpose Hand Tools

spark plug sockets
flex-handle ratchet (if needed)
point file
insulated spark plug pliers

Safety Equipment

eye protection

Basic Equipment

compressed air hose
compressed air gun
fender covers
spark plug cleaner (solvent)
spark plug gapper
spark plug feeler gauge
spark plug holder or tray
extension light

Reading List

The Student Guide has been carefully designed to provide you with only the information you need to know to complete each performance objective. If you would like additional information, however, you may wish to use the references below.

General References

Crouse, William H. ***The Auto Book.*** New York: McGraw-Hill, Inc., 1974, pp. 264, 362-364.

Crouse, William H. ***Automotive Mechanics.*** 7th ed. New York: McGraw-Hill Inc., 1975, pp. 300-302, 316-318.

Ellinger, Herbert E. ***Automechanics.*** 2nd ed. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1977, pp. 223-26.

Stockel, Martin W. ***Auto Mechanics Fundamentals.*** South Holland, Illinois: The Goodheart-Willcox Co., Inc., 1974, pp. 58-60.

42

Stockel, Martin W. *Auto Service and Repair.* South Holland, Illinois: The Goodheart-Willcox Co., Inc., 1975, pp. (21-22) -

Toboldt, William K. and Johnson, Larry. *Automotive Encyclopedia.* South Holland, Illinois: The Goodheart-Willcox Co., Inc., 1975, pp. 411-416.

Special-Purpose Reference

Crouse, William H. *Automotive Electrical Equipment.* 8th ed. New York: McGraw-Hill, Inc., 1976, pp. 203-204.

Personal and Service Safety Practices

Safety When Working around Spark Plugs

Vehicle finish. Always use fender covers when working under the hood. This will keep fenders from getting scratched.

Procedures. Follow correct procedures when disconnecting spark plug wires. This will prevent stretching and possibly breaking spark plug wires unnecessarily.

Always follow correct procedures and use the right tools when removing, gapping, and installing spark plugs. This will prevent damaging and possibly breaking spark plugs, thereby making them unserviceable.

Care of eyes. Always wear eye protection equipment when using compressed air to blow dirt from around the spark plugs and when sandblasting spark plugs. This will prevent dirt and other debris from getting into your eyes.

Safety Requirements When Working with Hydraulic Equipment

You may find it easier to remove and install spark plugs on some engines from under the vehicle. If you can easily get to the plugs without lifting the vehicle, these safety practices do not apply.

Hydraulic floor jacks and jack stands

- Place the jack securely under the vehicle frame.
- Slowly raise the vehicle with the jack.
- Always support the vehicle by placing the jack stand in a secure position under the vehicle.
- Store the jack handle. Do not leave it on the floor, where someone could trip over it.

Hydraulic lift equipment

- Never put more weight on the lift than its rated capacity. (You'll find the lift's rated capacity on the lift.)
- Never rock the vehicle while it's on the lift.
- Always be sure the vehicle is securely on the lift before you raise the lift.

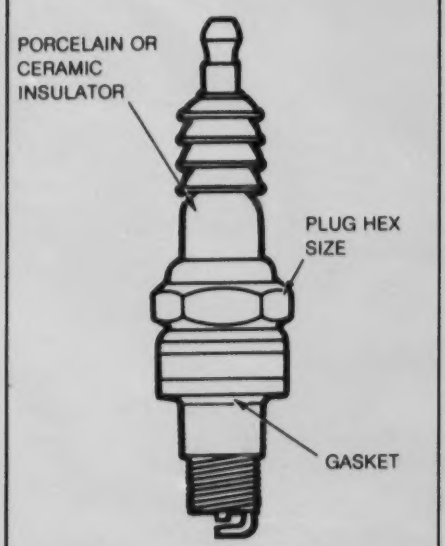
Safety in Work Clothing and Grooming

Hair. Keep hair away from the moving parts of an operating engine. Keep hair under a hat if it is longer than conventional length (over your shirt collar).

Jewelry. Avoid wearing any metal (rings, buckles, wristwatches, necklaces, etc.) that can come in contact with electricity. You can receive a severe burn if the metal you are wearing touches an electrical part. You could also damage the electrical unit.

Clothing. Avoid wearing loose clothing, since it can hang down and get caught in the moving parts of an operating engine. Injury can result. Loose clothing can also catch on engine parts and tear.

Figure 17-1 Spark Plug



Removing and Inspecting Spark Plugs

When servicing spark plugs, you must handle them carefully at all times. The upper porcelain or ceramic-like material of the spark plug can be easily broken if the right tools are not used for removing and installing them (see figure 17-1). Also, angling the tool on the spark plug can cause the porcelain to crack or break.

Figure 17-2 Disconnecting the Spark Plug Wire from the Spark Plug

Removing Spark Plugs

STEP 1 Disconnect the spark plug wire from the spark plug.

NOTE: Remember to twist the rubberlike boot back and forth first to break the seal. Then, pull the wire and boot straight up and away from the spark plug (see figure 17-2).

NOTE: To avoid burning your hands when the engine is hot, use a pair of insulated pliers to remove the spark plug wire.

STEP 2 Select the proper special spark plug socket to fit the plug hex size.

STEP 3 Select the ratchet, extensions, and universals necessary to reach the spark plugs in the engine (see figure 17-3). It

may be necessary on some V-8 engines to remove a few engine parts to get to the spark plugs.

Figure 17-3 Flex-Handle Ratchet Wrench

STEP 4 Loosen each spark plug one or two turns (see figure 17-4). Be careful not to tilt the wrench or you'll break the spark plug insulator.

- Use compressed air to blow the dirt particles from around the spark plugs away from the engine. This will keep dirt and debris from getting inside the cylinder once the spark plug is removed.

STEP 5 Remove all spark plugs and their gaskets. On those engines with aluminum heads, allow the engine to cool first.

NOTE: Spark plugs that have tapered seats do not use gaskets.

Figure 17-4 Removing the Spark Plugs

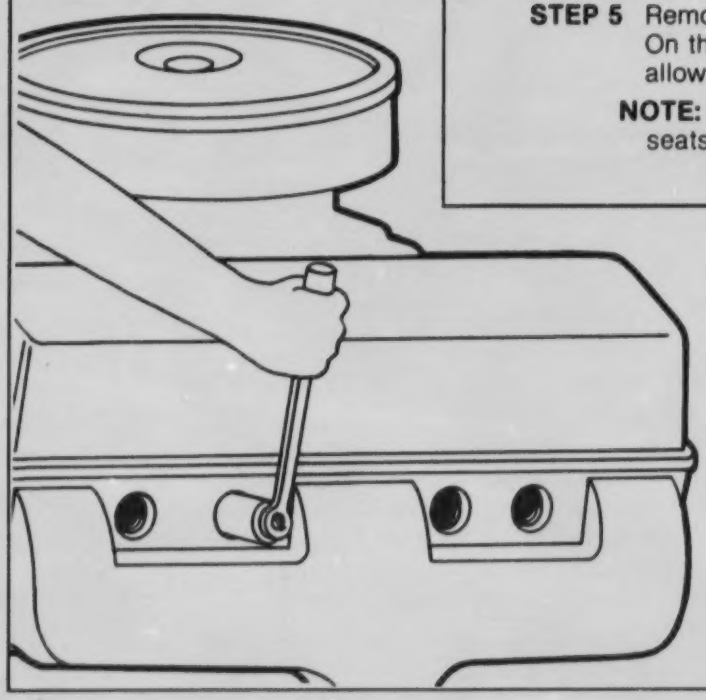


Figure 17-5 Removing Spark Plugs from a Slant-6 Engine

NOTE: On some slant-6 engines, the spark plugs are in metal tubes set into wells. Remove both the plug and the metal tube. Gaskets are not used (see figure 17-5).

- As each spark plug is removed, place it in a spark plug holder or tray (see figure 17-6). The old plugs should be arranged in the holder according to the cylinder and the side of the engine from which they were removed. This will help identify the cylinder when a defect on a particular spark plug is being diagnosed.
- Placing the spark plugs in the same order as the engine cylinders is a recommended procedure even if a tray or holder is not available.

Figure 17-6 Spark Plug Holder

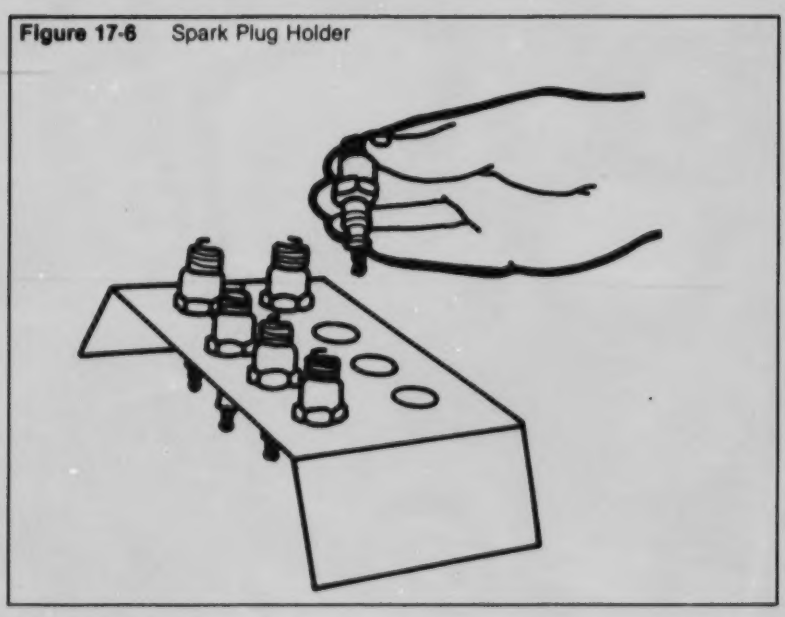
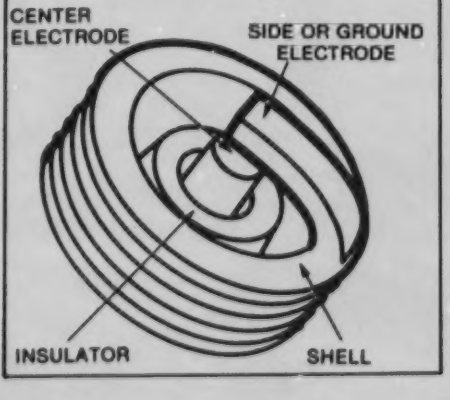


Figure 17-7 Areas to Check on a Used Spark Plug



Defects That May Develop in Spark Plugs

A careful examination of the used spark plugs is helpful in determining engine condition, spark plug heat-range selection, and trouble relating to operational conditions.

Inspect the side or ground electrode and the center electrode for wear and for any deposit buildup of carbon or oil (see figure 17-7). Inspect the insulator and shell for blisters or heavy deposits of carbon or oil.

Study the examples of spark plug defects. You'll notice that the defects are divided into two groups. The first

The following nine photographs are reprinted courtesy of Champion Spark Plug Company.

group shows those defects that can be cleaned up; in these cases, the spark plug can be regapped and then reused. The other group shows those defects that cannot be corrected; in these cases, the spark plug should be replaced with a new one.

Clean and gap spark plugs that are:

1. Identified by light tan or gray deposits on the firing tip (see figure 17-8).

2. Identified by deposit buildup from oil or carbon that closes the gap between the electrodes. If deposits are excessive and cannot be cleaned, replace the spark plug (see figure 17-9).

3. Identified by wet, black deposits on the insulator, shell surfaces, and electrodes (see figure 17-10). This is caused by excessive oil entering the combustion chamber. If you are not going to repair the engine to correct this condition, then replace the spark plug with one that has a "hotter" rating. You'll learn more about spark plug selection and heat ranges later in this performance objective.

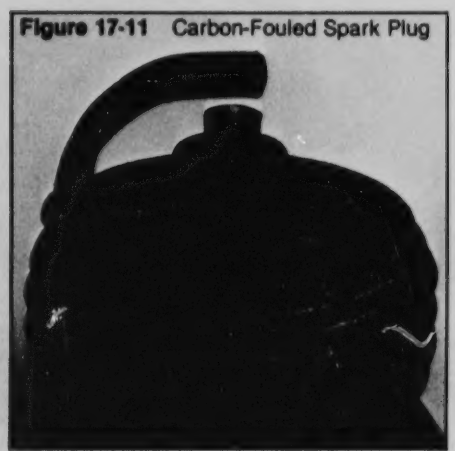
4. Identified by black, dry, fluffy carbon deposits on the insulator, shell surfaces, and electrodes. This condition is caused by too rich a fuel mixture, excessive idling, a dirty air cleaner, or too cold a spark plug. The spark plug can be cleaned (see figure 17-11).

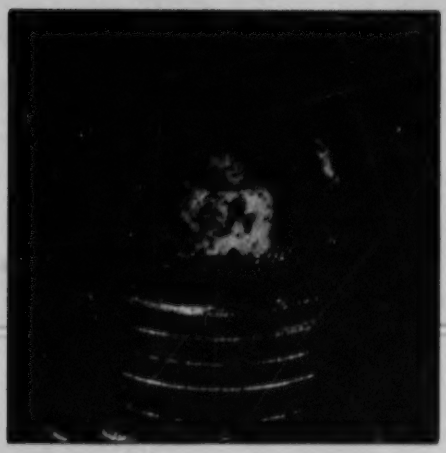
5. Identified by melted or spotty deposits that look like bubbles or blisters. This condition is caused by sudden acceleration. It can be cleaned unless it is excessive, in which case the spark plug should be replaced (see figure 17-12).

Replace spark plugs that are:

1. Identified by severely eroded or worn electrodes. This condition is caused by normal wear (see figure 17-13).

Figure 17-11 Carbon-Fouled Spark Plug





2. Identified by dark, gray, black, yellow, or tan deposits or by a fused, glazed coating on the insulator tip. This condition is caused by highly leaded gasoline (see figure 17-14).

3. Identified by melted electrodes and possibly a blistered insulator. This condition is caused by incorrect ignition timing, too "hot" a plug rating, the wrong type of fuel, or engine overheating (see figure 17-15).

4. Identified by a white or light gray insulator with small black or gray-brown spots. The electrodes will have a bluish-burnt appearance (see figure 17-16). This is caused by too "hot" a plug, incorrect ignition timing, the wrong type of fuel, or engine overheating.

Turn to your Review Exercise Book and complete Exercise 6.

Figure 17-13 Spark Plug with Worn Electrodes

Figure 17-15 Spark Plug Showing Signs of Preignition

Figure 17-14 [illegible] Spark Plug

Figure 17-16 Spark Plug that is Overheating

WORK ACTIVITIES

Before doing a work activity, make sure you've learned all the information that comes before it in the Student Guide. If you need a review, read the information on the pages listed in parentheses next to each work activity. Do not begin any of the work activities until you have your instructor's approval. If you're not sure that you can do a work activity, ask your instructor for help.

1. Remove the spark plugs from the engine (pages 42-44).

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

2. Examine and identify spark plug defects. Write down the defects you find, naming the cylinder from which each spark plug was removed (pages 44-46).

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

After you have finished this activity, go on to the next section.

Cleaning and Gapping Spark Plugs

Now that you have examined the set of spark plugs that you removed from the engine, you must decide whether they should be replaced or put back in the engine. Spark plugs are replaced, depending upon the following factors:

- mileage for which they have been used
- overall condition (defects)
- wear of the electrodes

They should by replaced every 7,000 to 10,000 miles, depending upon the vehicle manufacturer's recommendations.

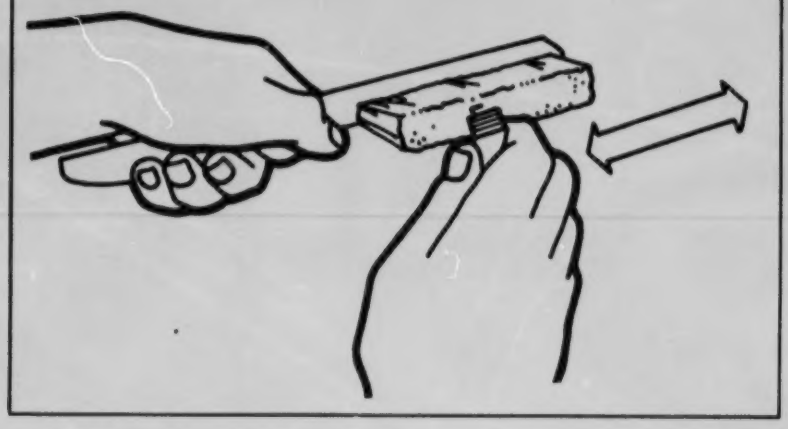
Generally, it is recommended that spark plugs be either replaced or reused as complete sets. For those spark plug sets that can be cleaned, regapped, and put back in the engine, you should follow the procedures below.

Cleaning. Remove the spark plugs from the holder and place them in solvent (see figure 17-17). Use a brush to remove all oil and varnish deposits.

Figure 17-17 Placing Spark Plugs in a Solvent Tank

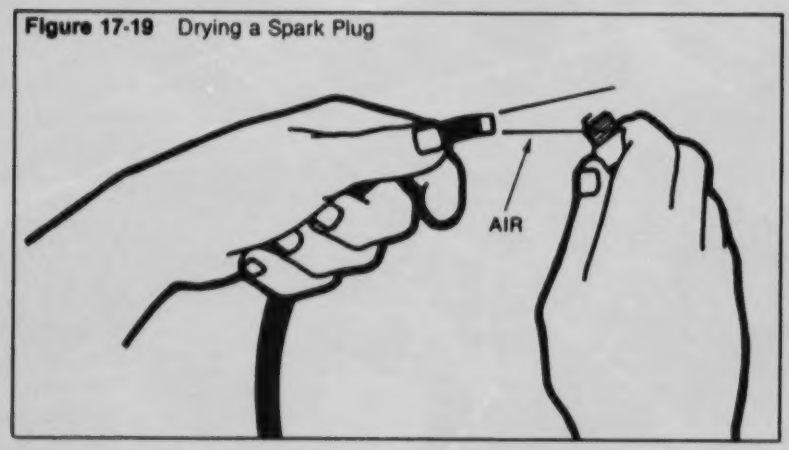
Use a wire brush to remove carbon and rust deposits from the spark plug threads (see figure 17-18).

Figure 17-18 Cleaning Spark Plug Threads



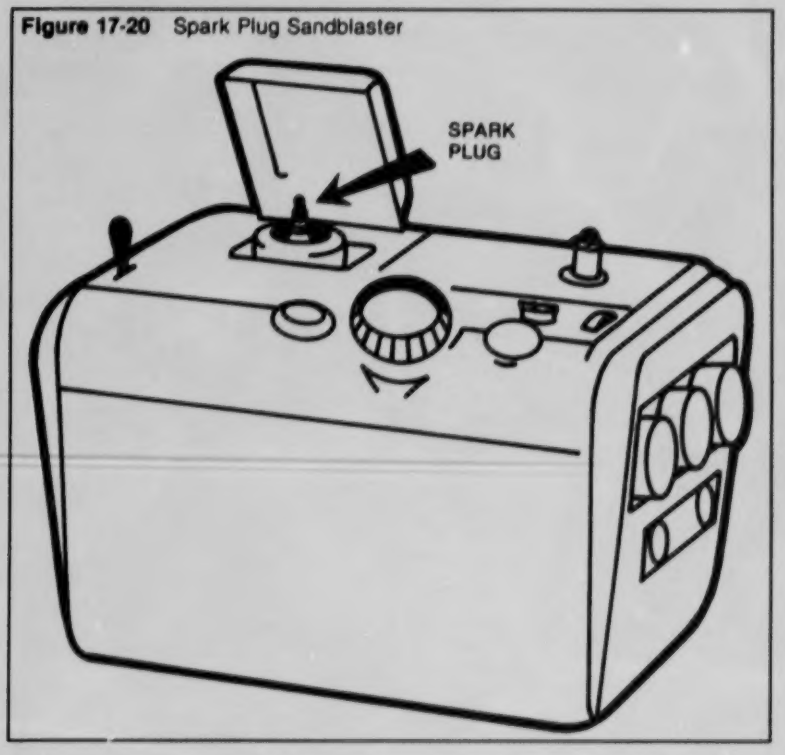
Thoroughly dry with compressed air to prevent the solvent from gumming or caking on the insulator of the spark plug (see figure 17-19).

Figure 17-19 Drying a Spark Plug



If an abrasive blast machine or sandblaster is available, sandblast each plug, closely following the equipment manufacturer's instructions (see figure 17-20).

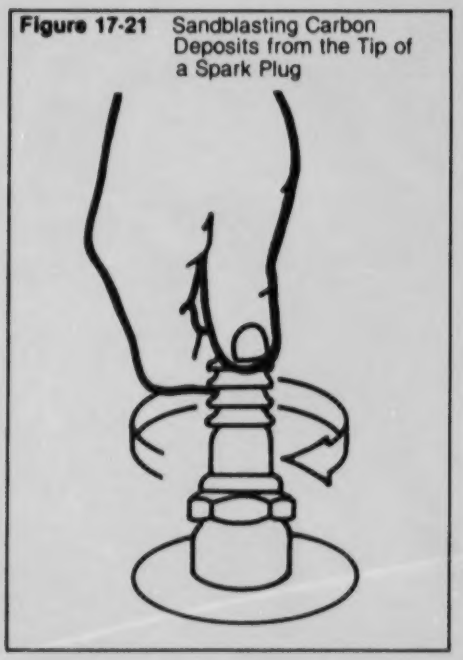
Figure 17-20 Spark Plug Sandblaster



NOTE: If you sandblast too long, you'll erode the insulator and damage the spark plug.

To remove the carbon deposit buildup on the tip of the spark plug, rotate the plug one complete turn while sandblasting. Then rotate again and use the air blast to remove the abrasives (sand) from the end of the plug (see figure 17-21).

Figure 17-21 Sandblasting Carbon Deposits from the Tip of a Spark Plug



After you have cleaned the spark plugs, look at them again to see if there are any fine cracks that you were unable to locate before cleaning them. Examine the insulator carefully both at the top and at the tip of the spark plug.

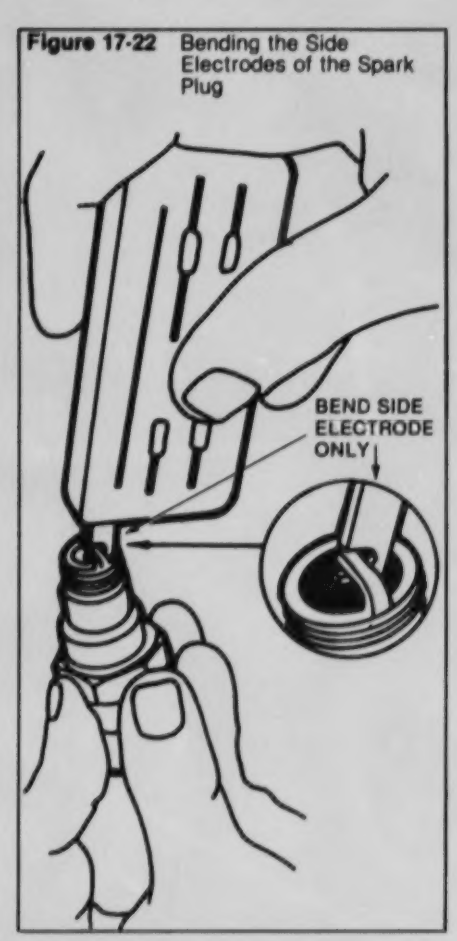


Figure 17-22 Bending the Side Electrodes of the Spark Plug

Filing. After cleaning the spark plugs, bend the side or ground electrode back just enough so that a small point file can fit between the two electrodes (see figure 17-22).

File the center electrode flat. Then, file the inside of the ground electrode until a shiny metal surface appears. Both electrodes should be flat and parallel to each other (see figure 17-23).

Remember, it takes less voltage to jump the electricity across electrodes that are flat with sharp edges than across those electrodes that are rounded over (see figures 17-24 and 17-25).

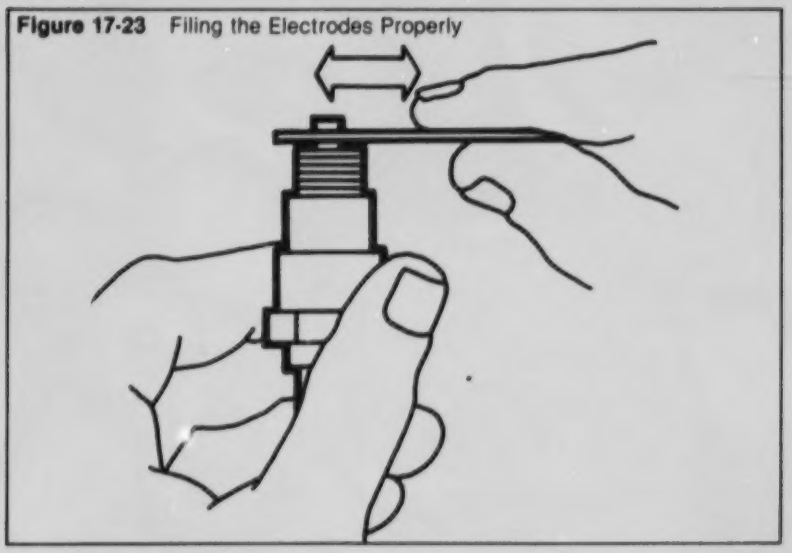


Figure 17-23 Filing the Electrodes Properly

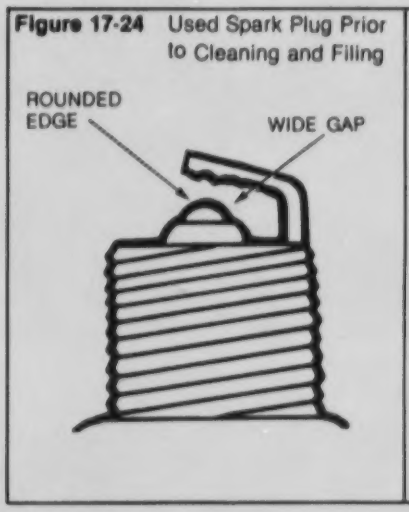


Figure 17-24 Used Spark Plug Prior to Cleaning and Filing

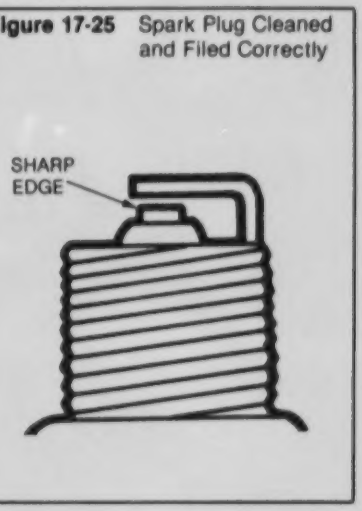


Figure 17-25 Spark Plug Cleaned and Filed Correctly

Gapping. The term *gapping* refers to the process of setting the air gap between the two spark plug electrodes to manufacturer's specifications. Set the gap after you have cleaned the spark plug tip of all deposits and have filed the electrodes flat.

For spark plug gap settings, refer to the specification decal in the engine compartment or to your technical service manual. The spark plug gap specification on the decal will look like the one in figure 17-26.

Figure 17-26 Specification Decal for Servicing a Vehicle

XK
140 CU. IN.
2 BBL. CARB.
GM 101-AIR COND.

VEHICLE EMISSION CONTROL INFORMATION
GENERAL MOTORS CORPORATION

CCS EXHAUST EMISSION CONTROL

MAKE ALL ADJUSTMENTS AT NORMAL OPERATING TEMPERATURE. CHOKE FULL OPEN. TRANSMISSION IN NEUTRAL EXCEPT WHERE NOTED. (CLUTCH PEDAL IS NOT TO BE DEPRESSED). AND AIR CONDITIONING OFF.

SET PARKING BRAKE AND BLOCK DRIVE WHEELS.

1. DISCONNECT FUEL TANK HOSE FROM VAPOR CANISTER.
2. DISCONNECT VACUUM ADVANCE HOSE AT THE DISTRIBUTOR AND PLUG.
3. DISCONNECT ELECTRICAL CONNECTION AT ANTI-DIESELING SOLENOID AND PROTECT LOOSE CONNECTOR FROM CONTACTING THE ENGINE COMPONENTS.
4. SET DWELL AND TIMING AT AN ENGINE SPEED OF 700 RPM OR LESS.
5. ADJUST CARBURETOR SPEED SCREW TO SPECIFIED RPM.
6. RECONNECT ELECTRICAL CONNECTION AT ANTI-DIESELING SOLENOID. WITH TRANSMISSION IN NEUTRAL. OPEN THROTTLE MOMENTARILY TO ALLOW SOLENOID PLUNGER TO EXTEND FULLY. ADJUST SOLENOID SCREW TO SPECIFIED RPM.
7. WITH TRANSMISSION IN NEUTRAL, SET FAST IDLE CAM TO HIGH RPM STEP WITH FAST IDLE CAM ON HIGH STEP. RECONNECT VACUUM HOSE IF A SPEED CHANGE IS NOTED. REFER TO SERVICE MANUAL FOR REPAIR OF TCS CIRCUIT.
8. RECONNECT FUEL VAPOR HOSE AT CANISTER.
9. DEPRESSING CLUTCH SHOULD CAUSE IDLE SPEED TO DROP FROM SOLENOID SCREW RPM SETTING TO CARBURETOR SCREW RPM SETTING.

SEE SERVICE MANUAL FOR ADDITIONAL INFORMATION

	TRANSMISSION	
	AUTOMATIC	MANUAL
DWELL	31-34°	31-34°
TIMING	8°BTDC	8°BTDC
SPARK PLUG GAP	035"	035"
CARB. SCREW (RPM)	550 (IN DRIVE)	300
SOLENOID SCREW (RPM)	800 (IN DRIVE)	1200

IDLE MIXTURE PRESET AT FACTORY. DO NOT REMOVE CAPS.

PRINTED IN U.S.A. THIS VEHICLE CONFORMS TO FEDERAL AND CALIFORNIA REGULATIONS APPLICABLE TO 1972 MODEL YEAR NEW MOTOR VEHICLES PT.NO. 6273493

Courtesy General Motors Corporation.

Look at the sample decal in figure 17-26. The spark plug gap specification for this vehicle and engine is .035 inch. The specification applies to this vehicle, regardless of whether it has an automatic or manual transmission.

The spark plug gap specification found in a technical service manual tune-up chart will look like the ones in figure 17-27.

Figure 17-27 Specifications for Spark Plug Gap

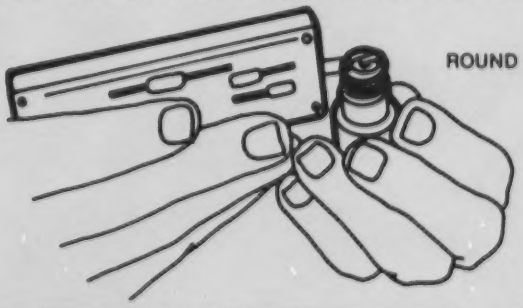
YEAR	SPARK PLUG TYPE	SPARK PLUG GAP INCH
Chevrolet 1975		
8-350 2-BBl. CARB.	----	.060
8-350	----	.060
Corvette 1973		
8-350, 190 H.P.	----	.035

Reading the chart, we learn that for a 1975 Chevrolet, V-8, 350 cc. engine with a 2-barrel carburetor, the spark plug gap is sixty-thousandths of an inch (.060″). The spark plug gap specifications for a 1973 Corvette, V-8, 350 cc. engine having one hundred and ninety horsepower is thirty-five-thousandths of an inch (.035″).

After you have found the gap specifications for the vehicle you're working on, measure the gap.

To measure the spark plug gap, insert a round, wire-type feeler gauge of the specified gap dimension between the plug electrodes (see figure 17-28).

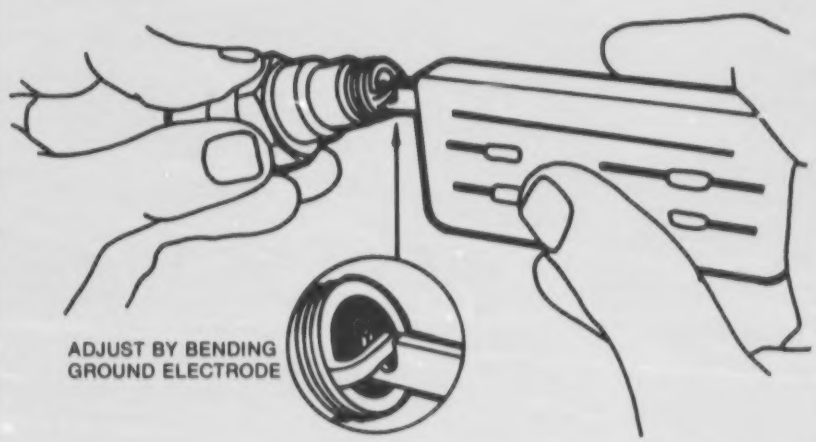
Figure 17-28 Gapping the Spark Plug with a Wire Feeler Gauge



Do not use a flat, leaf-type feeler gauge; it is not as accurate.

Then, with the special spark plug gapper or bending tool, bend the side (ground) electrode. ***Bend only the ground electrode*** (see figure 17-29).

Figure 17-29 Bending the Ground Electrode



Bend the ground electrode either toward the center electrode to close the gap, or away from the center electrode to open the gap.

CAUTION: Do not tap the electrode on a hard surface to adjust the gap. Doing this can break the insulator.

- When the feeler gauge "snaps through" between the two electrodes, the gap opening is correct.
- If the feeler gauge cannot pass between the electrodes without your forcing it through, the gap is too close.
- If the feeler gauge passes through between the electrodes but does not touch or just touches the electrodes, the gap is too wide.

Also, always check the spark plug gap setting on new plugs before you install them in the engine.

Turn to your Review Exercise Book and complete Exercise 7.

WORK ACTIVITIES

Before doing a work activity, make sure you've learned all the information that comes before it in the Student Guide. If you need a review, read the information on the pages listed in parentheses next to each work activity. Do not begin any of these work activities until you have your instructor's approval. If you're not sure that you can do a work activity, ask your instructor for help.

3. Clean and file the electrodes on a set of spark plugs (pages 47-50).

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

4. Adjust spark plug gaps to vehicle manufacturer's specifications (pages 51-53).

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

After you have finished this activity, go on to the next section.

Installing Spark Plugs

Before installing a set of spark plugs, there are three things you must do first.

- Select the proper spark plugs for the vehicle and engine in which they are to be installed. Look up the recommended part number given by the vehicle manufacturer. You should also check the part numbers on the old plugs to be sure those plugs are the correct ones.
- Select the proper spark plug heat range for the engine.
- Look up the spark plug torque specifications.

Spark plug part numbers. Look up the part number of the spark plug recommended by the vehicle manufacturer in the technical service manual. It will look like this:

Figure 17-30 How Spark Plug Numbers Appear in a Service Manual

YEAR	SPARK PLUG	
	TYPE	GAP INCH
Chevrolet 1975		
8-350 2-BBl. CARB.	R44TX	—
8-350	R44TX	—
Corvette 1973		
8-350, 190 H.P.	R44T	—

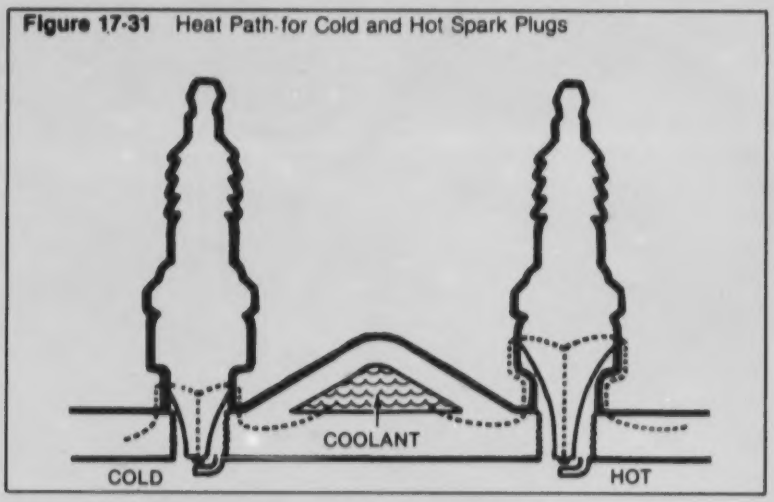
Upon reading the chart, as before, we learn that for a 1975 Chevrolet V-8, 350 cc. engine with a 2-barrel carburetor, the spark plug part number is R44TX. You'll notice that for a 1973 Corvette, V-8, 350 cc. engine having 190 horsepower, the spark plug number is R44T. The part number of the spark plug is shown on the insulator of the plug.

Spark plug heat range. The spark plug heat range is controlled by the length of the insulator that is exposed to the heat of combustion.

- When the heat has a short way to travel to the cooling system because the insulator is short, it is called a "cold" plug — the heat transfers quickly.
- When the heat has a long way to travel to the cooling system because the insulator is longer, it is called a "hot" plug — the heat transfers slowly (see figure 17-31).

The heat range of a spark plug (hotter or colder) is first established by the vehicle manufacturer. Then, after the engine has been in service for a period of time, spark plug heat ranges are selected by the condition of the old, used plugs.

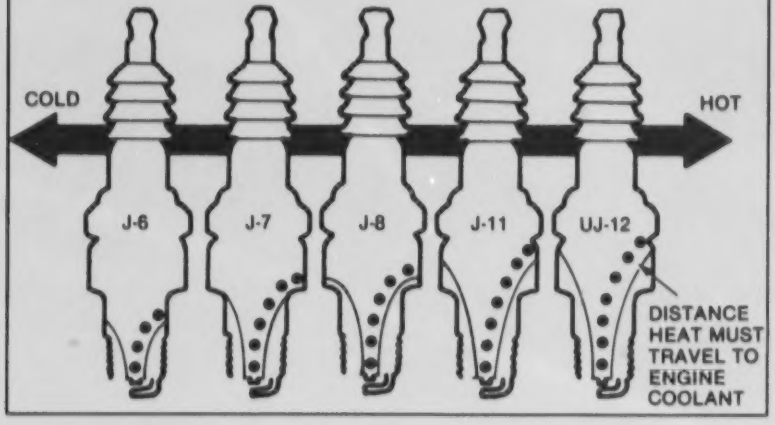
Figure 17-31 Heat Path for Cold and Hot Spark Plugs



- Black, oily deposits on the tip of the spark plugs indicate that the engine needs a hotter plug to keep the spark plug clean of these deposits.
- White, blistered insulators and rapid erosion of the electrodes indicate that the engine needs a colder plug to avoid these conditions.

You'll notice in figure 17-32 that as the spark plug number increases to a higher number, the "hotter" the spark plug selection becomes. For example, spark plug J-11 is a hotter plug than J-6.

Figure 17-32 Plug Sizes for Heat Flow



To further illustrate, one spark plug manufacturer lists the spark plugs by heat range. The listings look something like those in figure 17-33.

Figure 17-33 List of Heat Ranges for Spark Plugs

THREAD SIZE	HEAT RANGE	REGULAR (Non-resistor) TYPES
14 MM 3/8" reach 13/16" Hex	HOT ↓ COLD	UJ-12 J-11 J-8, UJ-8 J-7 J-6 J-6, UJ-6 J-5 J-4

Notice that the same size plug has several different heat ranges. All these spark plugs are the same size, but spark plug #J-4 is classified as a cold plug while # UJ-12 is the hottest plug of the size listed. Whenever you are changing to a different heat range, it is recommended that you select the spark plug with the next highest part number. Move up one part number at a time. The spark plug number furnished by the vehicle manufacturer is considered to be standard in relation to the heat range scale and is recommended for the engine.

Spark plug torque specifications. You'll also need to know how tight to tighten the spark plugs when you are installing them.

If spark plugs are not tightened properly, the heat range ratings will change because of improperly sealed gaskets. Overtightening spark plugs will also cause the air gap settings to change, since overtightening will distort the ground electrode.

Again, refer to the technical service manual for the vehicle manufacturer's specifications on torquing spark plugs. The chart, which will be called "Engine Tightening Specifications," will look like figure 17-34. The example is taken from the Chevrolet section of the manual.

Figure 17-34 List of Tightening Specifications for Spark Plugs

YEAR	ENGINE MODEL	SPARK PLUGS ft-lbs.
1971-73	8-307	15
1970-74	8-400	25

Upon reading the chart, we learn that for 1971-73 Chevrolets, V-8, 307 cc. engines, the spark plug torque specification is 15 ft-lbs. For 1970-74 Chevrolets, V-8, 400 cc. engines, the torque specification is 25 ft-lbs.

Where spark plug torque specifications required by the vehicle manufacturer are very specific, the spark plug manufacturer provides a specification range. You can use either the specifications from the vehicle manufacturer or the ones from the spark plug manufacturer.

Look at the "Recommended Installation Torque" table in figure 17-35, which is the one available from the spark plug manufacturer. You'll notice that the table provides information concerning the thread size of the spark plug, and indicates whether the spark plug is installed in a cast iron cylinder head or an aluminum cylinder head. Directions are also given for the correct tightness of the spark plug, both without a torque wrench (w/o Torque wrench) and with a torque wrench (w/ Torque wrench). However, use of a torque wrench is recommended.

RECOMMENDED INSTALLATION TORQUE

Figure 17-35 Spark Plug Manufacturer's Table

SPARK PLUG THREAD SIZE	CAST IRON HEADS		ALUMINUM HEADS	
	w/Torque Wrench	w/o Torque Wrench	w/Torque Wrench	w/o Torque Wrench
GASKET TYPE				
10mm	8-12 lb. ft.	1/4 Turn	8-12 lb. ft.	1/4 Turn
12mm	10-18 lb. ft.	1/4 Turn	10-18 lb. ft.	1/4 Turn
14mm	26-30 lb. ft.	1/4 to 3/8 Turn	18-22 lb. ft.	1/4 Turn
18mm	32-38 lb. ft.	1/4 Turn	28-34 lb. ft.	1/4 Turn
TAPERED SEAT				
14mm	7-15 lb. ft.	1/16 Turn (Snug)	7-15 lb. ft.	1/16 Turn (Snug)
18mm	15-20 lb. ft.	1/16 Turn (Snug)	15-20 lb. ft.	1/16 Turn (Snug)

Mazda Rotary Engine requires only 8-13 lb. ft. (1/4 turn)

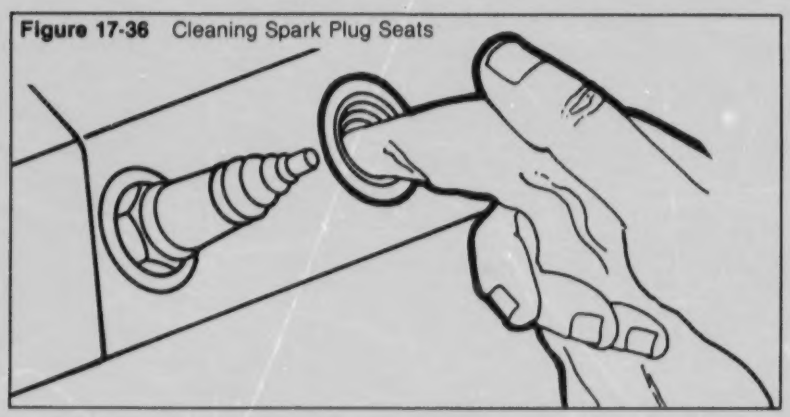
From *Automotive Service Manual. RJ12Y Spark Plugs, 870 Spark Plugs, and L-88A Spark Plugs.* ©1974 Champion Spark Plug Company Used with permission of Champion Spark Plug Company.

Installation procedures. To properly install the spark plugs in the engine, follow these step-by-step procedures:

STEP 1 Install the spark plug gaskets onto the spark plugs. Use new gaskets where needed, if available.

STEP 2 With a clean cloth, clean the spark plug seats in the cylinder head (see figure 17-36).

Figure 17-36 Cleaning Spark Plug Seats



STEP 3 Install the spark plugs finger-tight. If the plug does not thread into the port opening easily, you may have to use a thread-chaser (tap) to clean up the threads in the cylinder head.

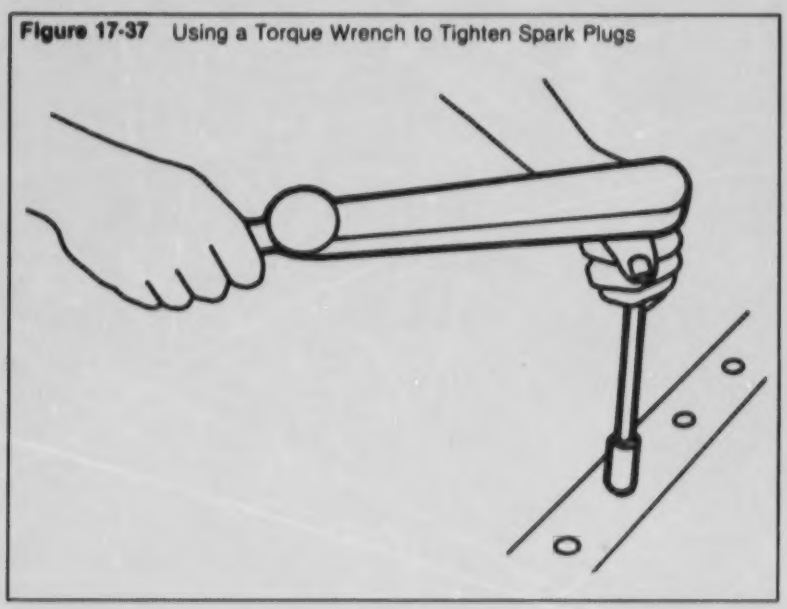
CAUTION: It is very important that the spark plug threads fit easily into the cylinder head. Incorrect torquing of the spark plug will result if they do not. The correct fit affects tightness and the ability of the spark plug to transfer heat to the cooling system.

STEP 4 Tighten each spark plug with a torque wrench as specified by the vehicle manufacturer (see figure 17-37). Be careful not to place any side pressure on the wrench. Side pressure will tip the socket and break the spark plug insulator.

- Overtightening the spark plugs can change the gap and cause other damage.
- Undertightening will cause the plug to overheat and possibly cause preignition.

STEP 5 Wipe the plug insulators clean and attach the spark plug wire. Be careful to keep the correct firing order.

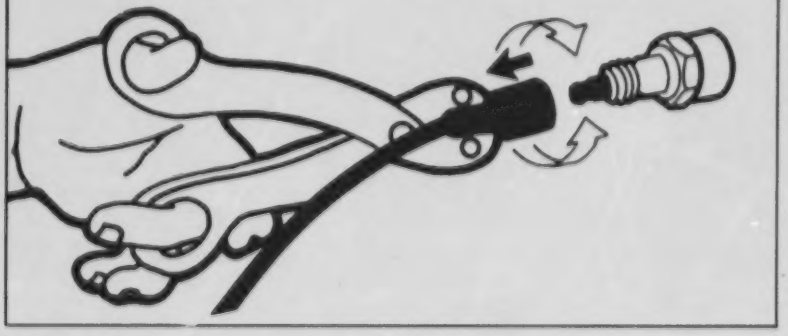
Figure 17-37 Using a Torque Wrench to Tighten Spark Plugs



Making an operational check. Finally, you will make an operational check of spark plug operation.

- Start the engine; with the engine running, pull each spark plug wire in turn. Be sure to use a pair of insulated pliers so that you won't burn your hands or receive any shocks (see figure 17-38).

Figure 17-38 Using Insulated Spark Plug Pliers to Reinstall Spark Plug Wires



- The engine RPM should decrease as you remove the wire.
- Also, the engine should noticeably miss.

If these engine conditions do not take place, test the spark to the spark plug and/or remove the spark plug and inspect it.

Testing spark plugs with a scope will be covered later in this unit.

Turn to your Review Exercise Book and complete Exercise 8.

WORK ACTIVITIES

Before doing a work activity, make sure you've learned all the information that comes before it in the Student Guide. If you need a review, read the information on the pages listed in parentheses next to each work activity. Do not begin any of the work activities until you have your instructor's approval. If you're not sure that you can do a work activity, ask your instructor for help.

5. Select the correct spark plugs (according to part number, heat range, and torque specifications) to be installed in an engine (pages 54-58).

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

6. Install a set of spark plugs in the engine (pages 59-60).

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

7. Make an operational check of the spark plugs following installation (page 60).

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

When you have finished these activities, ask your instructor to return your pretest on Performance Objective 17. Complete the questions that you missed or were unable to answer the first time you took the pretest. Check your answers with your instructor when you finish. Your instructor will tell you if you are ready to be checked off on the performance checklist, or if you need to correct some of your answers first.

If you are told by your instructor that you are ready for the performance checklist, carefully tear the checklist out of your Review Exercise Book and give it to your instructor.

PERFORMANCE OBJECTIVE 18

ANALYZE ENGINE PERFORMANCE

INTRODUCTION

In this performance objective you'll learn how to analyze engine performances, particularly those pertaining to the secondary ignition circuit. Because you will use an engine analyzer and scope extensively, you may wish to refer to Unit 3, Performance Objective 13, for a review of scope engine hookups and scope patterns.

After you have finished all the activities for Performance Objective 18, your instructor will use a checklist like the one that follows to evaluate vour work.

Performance Checklist—P.O. 18

Your instructor will provide either a live vehicle or live engine for this objective. Analyze the engine performance, using an engine analyzer and scope, and correct any problems you find. All the performances below must be accomplished.

Student Performances	Instructor Ratings		
	Acceptable	Not Acceptable	Omit
1. Hooks up analyzer leads to engine.			
2. Checks for proper engine idle, speed, idle mixture, and dwell; makes necessary adjustments.			
3. Checks over all secondary circuit performance, and records any defects.			
4. Checks available coil voltage and secondary circuit insulation, and records results.			
5. Checks spark plug firing voltages and performances, and records results.			
6. Checks distributor cap-to-rotor air gap, and records results.			
7. Checks for these engine-related problems: oily combustion chamber, fouled spark plug, leaking exhaust valve, and fuel starvation; records results.			
8. Makes minor adjustments as necessary.			
9. Uses proper tools and equipment.			
10. Follows all appropriate safety precautions.			
11. Does performance in an acceptable amount of time.			

SAMPLE

Tools and Equipment

You will need to use the following tools and equipment when you do the work activities for Performance Objective 18. You should already be able to use a basic hand tool set, so no procedures are provided here. The procedures for using special tools and equipment will be provided as you work through the activities in this Student Guide.

Basic Hand Tool Set

Special-Purpose Hand Tools

insulated pliers (spark plug leads)

Basic Equipment

fender covers
extension light

Special Equipment

engine analyzer
oscilloscope

Reading List

The Student Guide has been carefully designed to provide you with only the information you need to know to complete each performance objective. If you would like additional information, however, you may wish to use the references below.

General References

Crouse, William H. ***Automotive Mechanics.*** 7th ed. New York: McGraw-Hill, Inc., 1976, pp. 208-13.

Stockel, Martin W. ***Auto Service and Repair.*** South Holland Illinois: The Goodheart-Willcox Co., Inc., 1975, pp. (21-29) - (21-30).

Special-Purpose References

Crouse, William H., ***Automotive Electrical Equipment.*** 8th ed. New York: McGraw-Hill, Inc., 1976, pp. 208-13.

Johnson, James A., ***Automotive Diagnosis and Tune-Up.*** New York: McGraw-Hill, Inc., 1972, pp. 209-327.

Wetzel, Guy F., ***Automotive Diagnosis and Tune-Up.*** 6th ed. Bloomington, Ill.: McKnight Publishing Co., 1974, pp. 186-204.

Whited, N. W., ***Automotive Oscilloscope.*** New York: Delman Publishers, 1972, pp. 49-85.

Personal and Service Safety Practices

Safety When Making an Electrical Test

Procedures. Follow the procedures described by the manufacturer of the electrical test equipment. This includes proper care and use of the equipment, as well as proper calibration of the equipment.

Electrical tests. Never do any electrical tests when you are standing in water or when the vehicle or engine parts are wet. A painful shock may result.

Safety When Making Ignition Tests with an Oscilloscope

Care of scope. Always keep scope leads away from fan belts and engine fan blades. Damaged scope leads are expensive to replace.

Connections. Be sure that all test leads are properly connected and comply with the equipment manufacturer's instructions.

Safety When Working around an Operating Engine

Vehicle Finish. Always use fender covers when working under the hood. This will keep fenders from getting scratched.

Personal safety. Do not reach into the engine without first looking. Your fingers could get caught in the moving parts. Serious injury may result.

Safety in Work Clothing and Grooming

Hair. Keep hair away from the moving parts of an operating engine. Keep hair under a hat if it is longer than conventional length (over your shirt collar).

Clothing. Avoid wearing loose clothing, since it can hang down and get caught in the moving parts of an operating engine. Injury can result. Loose clothing can also catch on engine parts and tear.

Jewelry. Avoid wearing any metal (rings, buckles, wristwatches, necklaces, etc.) that can come in contact with electricity. You can receive a severe burn if the metal you are wearing touches the electrical unit. You could also damage the electrical unit.

Procedures for Testing the Secondary Ignition Circuit with Oscilloscope

The following tests let you check out the secondary ignition circuit, including its components. You start by testing the overall performance of the secondary circuit. Then, you test the secondary insulation (the wiring), the spark plugs, the distributor cap, and the rotor, in that order. Finally, you do other related engine tests. You use a scope with these tests, and you look at the firing lines and the firing section of the waveform.

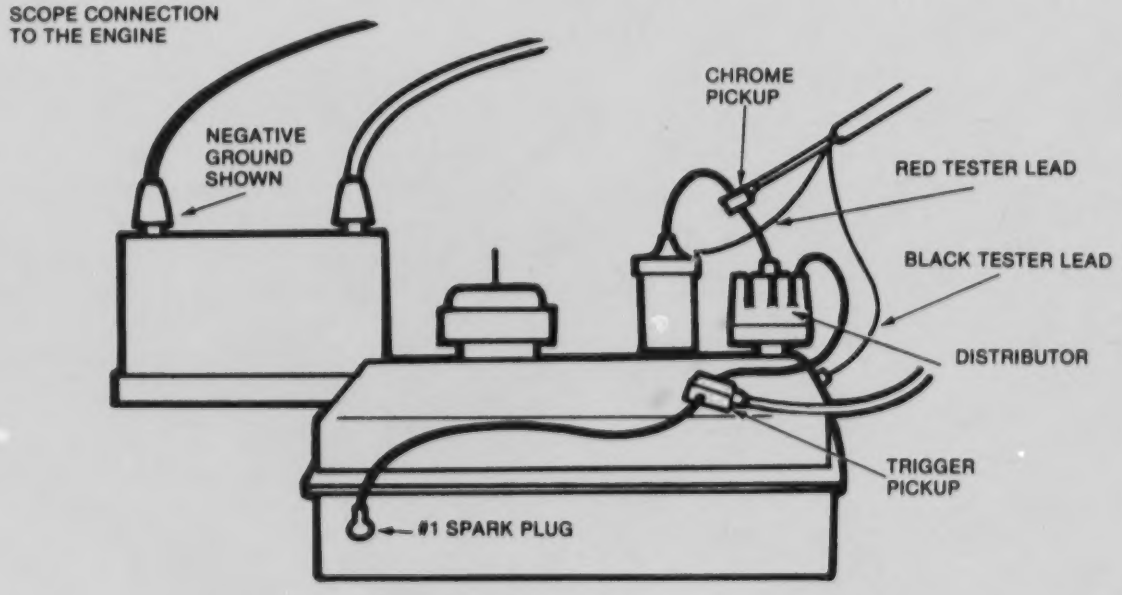
Scope Hookup to Engine

As the first step, you'll hook the scope up to the engine. Always follow the manufacturer's instructions for proper engine connections.

Here is a brief review of the scope connections that were described in Unit 3, Performance Objective 13.

STEP 1 Clamp the chrome pattern pickup around the coil high-tension lead (see figure 18-1).

Figure 18-1 Scope Connection to the Engine



STEP 2 Connect the red primary tester lead to the "Dist" terminal of the coil primary.

STEP 3 Connect the black ground tester lead to the engine block.

STEP 4 Clamp the red trigger pickup around the #1 spark plug wire near the distributor cap.

STEP 5 Connect the leads to the battery terminals.

Overall Secondary Ignition Circuit Tests

- *Loose secondary coil wire test.* This first test lets you see if you have a secondary pattern at all. The test is performed because a loose secondary coil wire or a loose secondary pattern pickup connection will create an incorrect pattern right away.

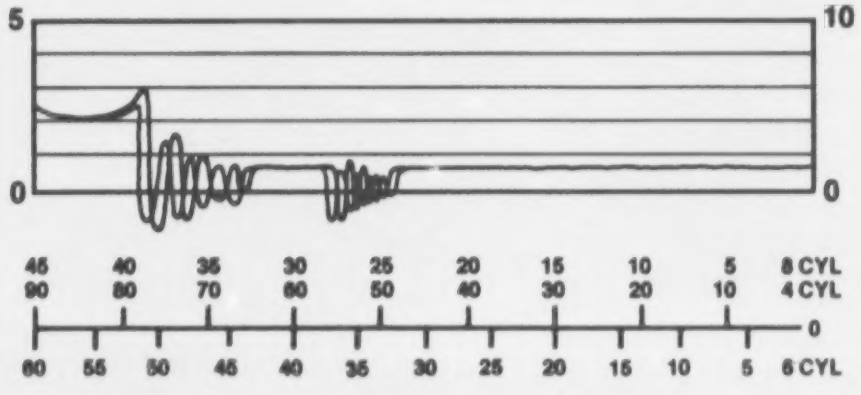
To test:

STEP 1 Turn the scope control to the secondary circuit selection.

STEP 2 Turn the pattern selection knob to the superimposed position.

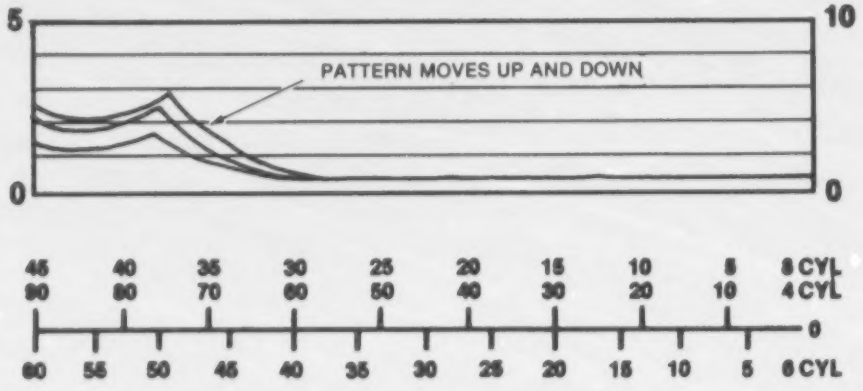
STEP 3 Operate the engine at fast idle (1,500 RPM) and observe the pattern (see figure 18-2).

Figure 18-2 Scope Showing Normal Secondary Superimposed Pattern



BAD The pattern at the left side of the screen moves up and down between high and low positions. This shows that the coil wire or the engine pattern pickup is loose (see figure 18-3).

Figure 18-3 Superimposed Pattern Showing Loose Coil Wire



- *Open secondary ignition circuit test.* This test of the secondary ignition circuit, done at the beginning, lets you find out if a spark plug wire is broken or separated from the spark plug. If a wire is separated from a spark plug or is broken, the secondary circuit will be open.

To test:

STEP 1 Continue to operate the engine at fast idle (1,500 RPM) as you did for the first secondary circuit test.

STEP 2 Turn the scope control to the display pattern position.

STEP 3 Look at the patterns (see figure 18-4 and 18-5).

Figure 18-4 Normal Display Pattern

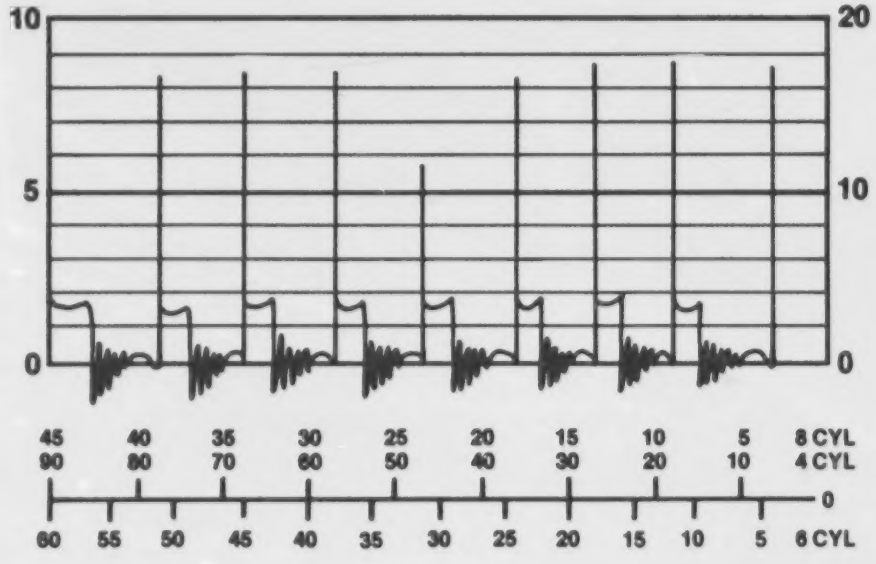
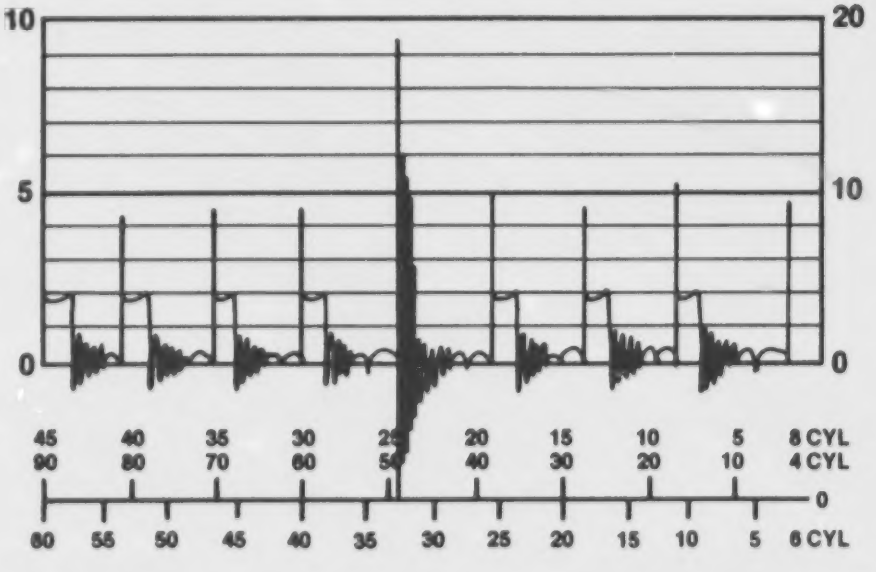


Figure 18-5 Display Pattern Shows Abnormal #6 Cylinder



BAD One cylinder shows a much higher firing line (spike), and a longer downward spike than those of the others (see figure 18-5). This indicates that there is an "open" in the secondary circuit caused by a bad spark plug wire that is either broken or separated from the spark plug. Notice also that a number of oscillations appear in the firing section immediately following the high firing line.

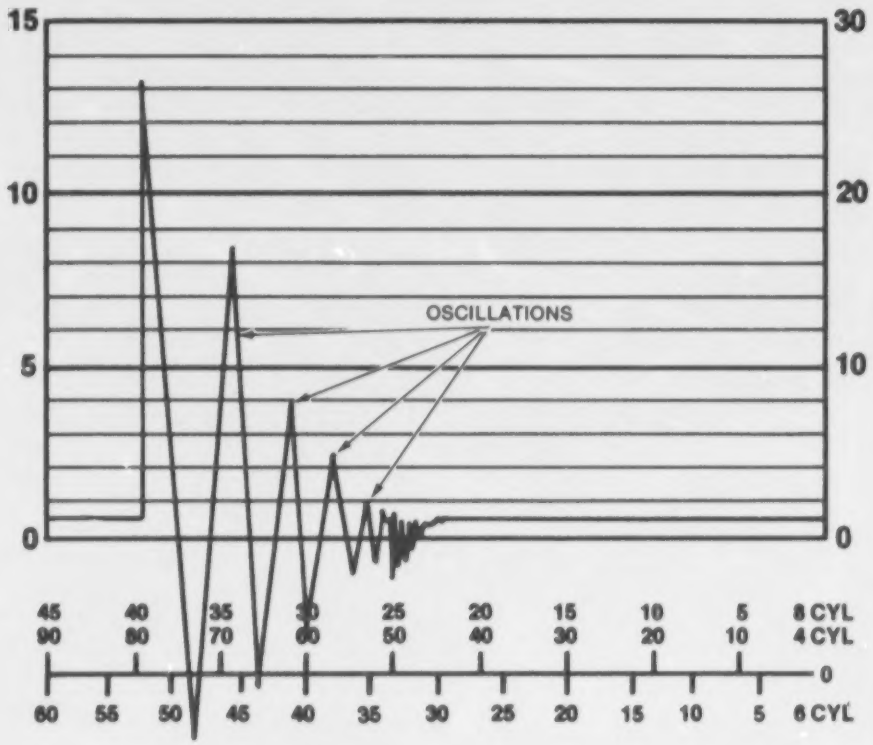
- To locate the cylinder with the problem, remember that the engine firing order on the display pattern begins with the firing line of the #1 cylinder, at the extreme right-hand side of the screen. In figure 18-5, for example, the #6 cylinder in the firing order is the one showing an "open" in the secondary circuit.

NOTE: Throughout this performance objective, the illustrations will use the firing order of 1-8-4-3-6-5-7-2 for a V-8 engine and 1-5-3-6-2-4 for a straight 6-cylinder engine.

- To get a better picture of what the firing section looks like, adjust the scope control so that it will extend the waveform horizontally (see figure 18-6). In the example you'll see not a firing line, but the telltale oscillations in the firing section.

NOTE: It's possible that you may not be able to do this on your scope, because not all scopes and scope models are the same.

Figure 18-6 Scope Showing an Open Secondary Circuit



- Figure 18-6 is an example of an open secondary circuit. The pattern has been extended horizontally so that the oscillations can be seen clearly.

  Secondary ignition circuit resistance test. This test lets you find out if the individual secondary circuit to each spark plug is normal or if it offers too much resistance to the current flow.

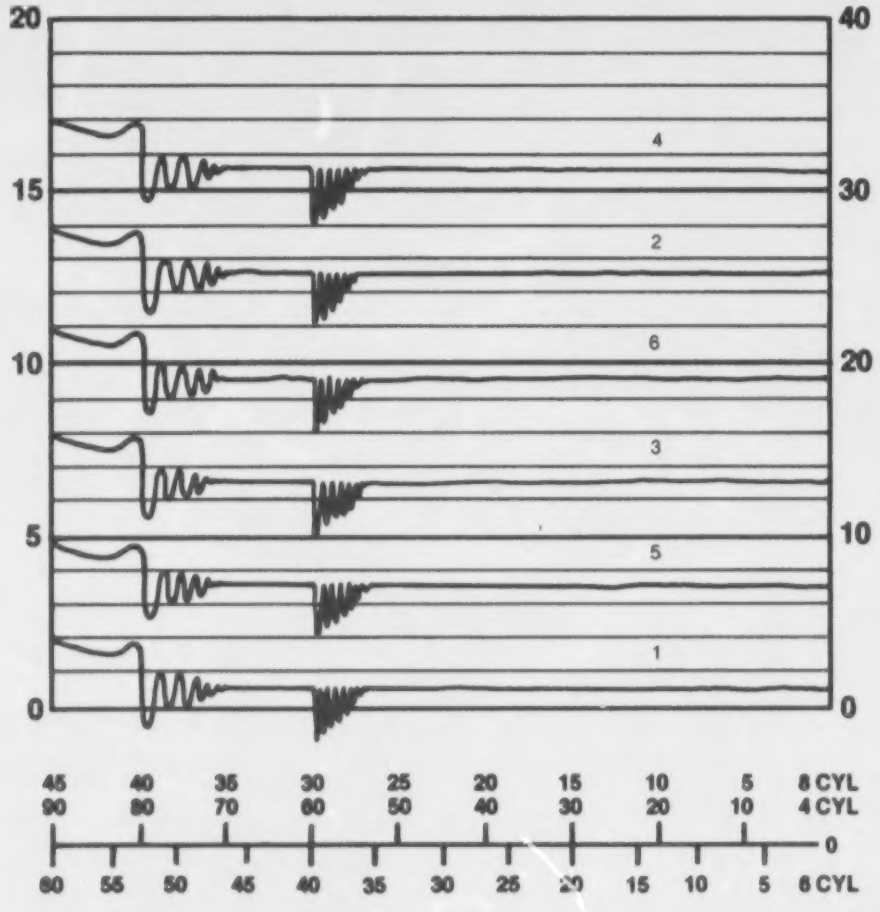
STEP 1 Turn the pattern selector to the secondary raster position.

STEP 2 Speed the engine up to about 1,500 RPM.

STEP 3 Look at the spark lines for sameness in length, height, and level, and for oscillations or wiggles.

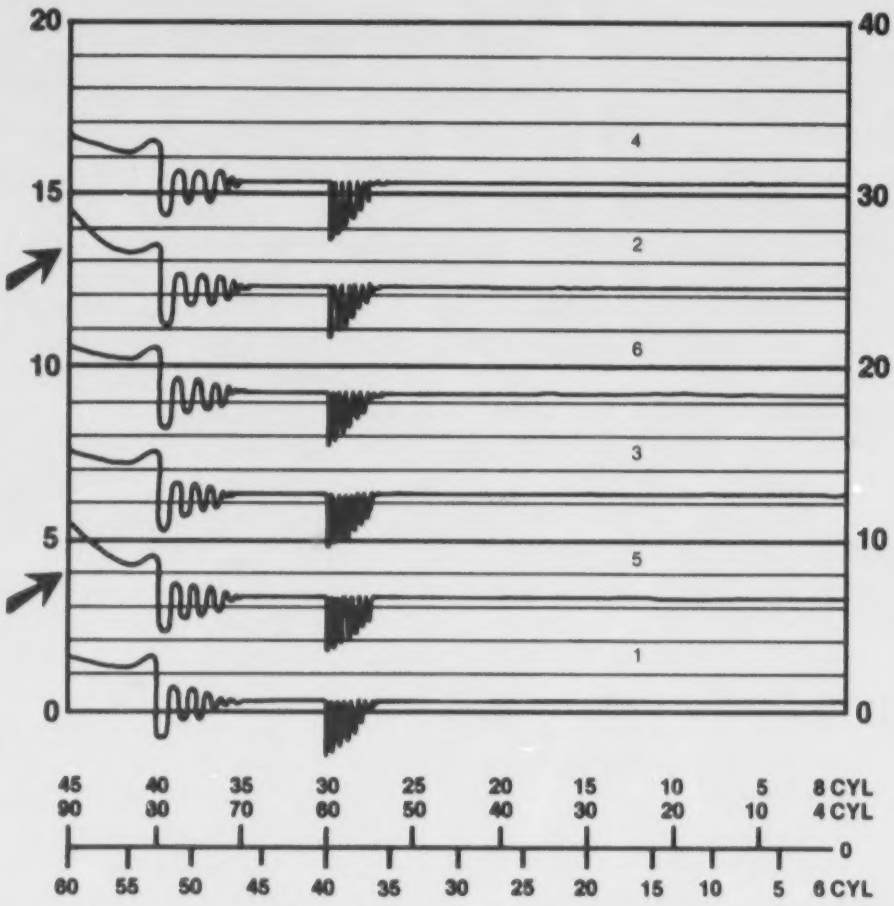
GOOD The spark lines above show a normal secondary raster pattern on a 6-cylinder engine (see figure 18-7). The spark lines are nearly level and about the same length, with little or no oscillation.

Figure 18-7 Scope Showing Normal Secondary Raster Pattern on a 6-Cylinder Engine



BAD The spark line slopes upward too much (cylinders #5 and #2 in figure 18-8). This pattern indicates that there is too much secondary resistance in the spark plug, in the spark plug wire, or in the individual distributor cap towers for cylinders #5 and #2.

Figure 18-8 Scope Showing Secondary Resistance in Spark Plugs #2 and #5



When all the spark lines slope excessively, there is excessive resistance in the coil wire, in the center tower of the distributor cap, or in the rotor.

Spark lines that are too long indicate a fouled spark plug or a shorted spark plug wire.

- ***Available secondary coil voltage test.*** This test lets you find out if the ignition system is capable of providing enough voltage to fire the spark plugs under normal operating conditions.

STEP 1 Select the 40 kv scale and turn the pattern selection knob to the display position.

STEP 2 Operate the engine at 1,500 RPM.

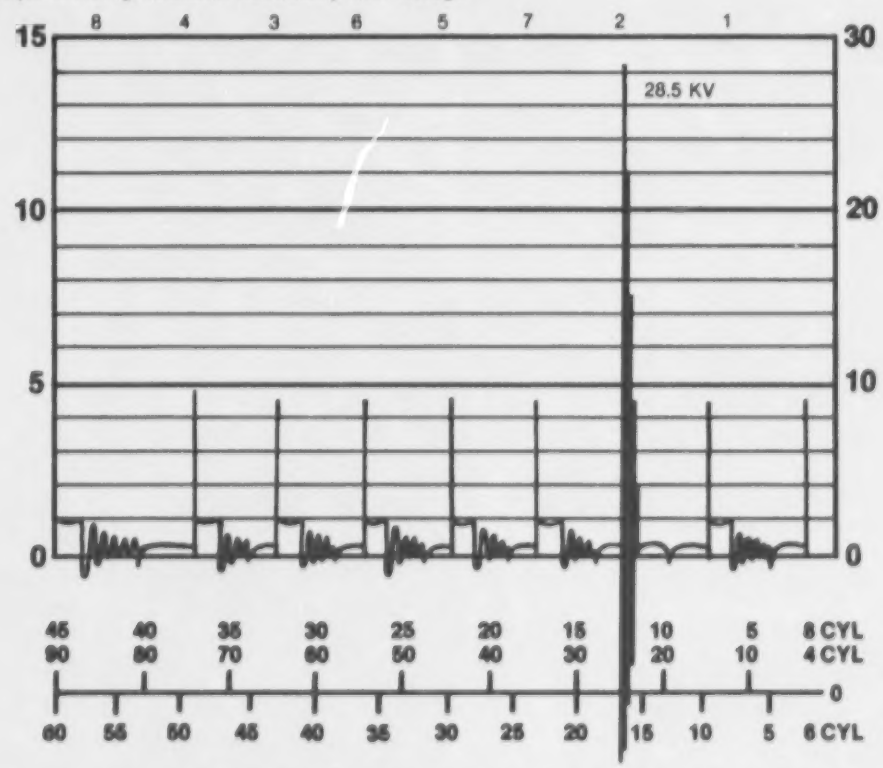
STEP 3 Using insulated pliers, disconnect one of the spark plug wires from its spark plug. Hold the wire away from ground.

NOTE: On vehicles with catalytic converters, the spark plug wire should be removed for no more than 30 seconds. During this brief time, you must also perform the cap-and-rotor leakage test and the rotor air gap test. You'll learn to do these tests later in this performance objective.

STEP 4 Look for the highest point in the scope pattern and note the reading.

STEP 5 Reduce engine speed to idle, and reconnect the spark plug wire to the plug.

Figure 18-9 Scope Showing Available Secondary Coil Voltage



GOOD The highest part of the firing line reaches to more than 20 kv (see figure 18-9). This is as it should be unless otherwise specified by the manufacturer.

BAD The output fails to reach 20 kv. Before assuming that the coil is completely to blame, check the dwell period. Also check for poor secondary circuit insulation (wires) and for resistance in the primary circuit. If everything checks out okay on these tests, test the coil and the condenser.

- ***Secondary ignition circuit insulation test.*** This test lets you find out if the insulation of the secondary circuit, including the distributor cap, the rotor, the coil wire, and the spark plug wires, is capable of handling the high voltages produced by the coil.

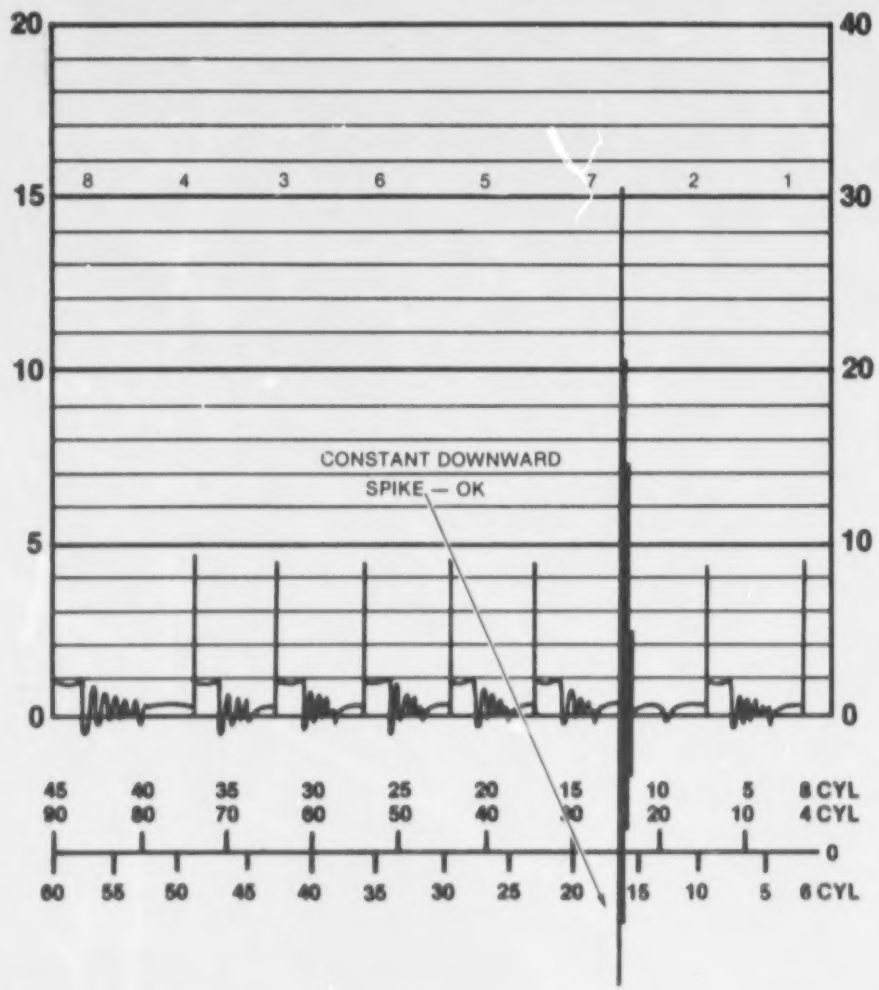
STEP 1 Repeat Steps 1, 2, and 3 as you did for the available voltage test (see page 76).

STEP 2 Look at the downward spike on the pattern of the cylinder being tested.

STEP 3 Reduce engine speed to idle, and reconnect the spark plug wire to the plug.

GOOD The downward spike is constant. The lower portion of the line should be about half as long as the upper portion, and must be steady (see figure 18-10).

Figure 18-10 Scope Showing the Performance of the Secondary Ignition Circuit Insulation



BAD The downward spike moves up and down or is absent. This indicates that there is a breakdown in the secondary circuit.

- Do this test with two or three other cylinders. If the next two or three cylinders also show a bad downward spike (one that is unsteady or absent), you can assume that this fault is common to all the cylinders. If this is the case, the rotor, the center terminal of the distributor cap, the coil wire, and coil need to be checked further.

- If only one cylinder shows a bad downward spike, the fault is in the spark plug wire.
- To locate the cylinder with the problem, remember that the engine firing order on the display pattern begins with the firing line of the #1 cylinder, at the extreme right-hand side of the screen. In figure 18-10, the #7 cylinder is the one being tested.

To summarize:

To complete the overall secondary ignition circuit tests, you should:

- First, test for a possible ***loose secondary coil wire*** at engine idle RPM, using a superimposed pattern.
- Then, test for a possible ***open circuit*** at engine fast idle (1,500 RPM), using a display pattern.
- Then, test the ***individual circuits*** to the spark plugs at 1,500 RPM, using a raster pattern.
- Then, switch back to the display pattern at 1,500 RPM and disconnect a spark plug wire to test the ***available coil voltage.***
- Finally, test the ***insulation of the secondary circuit*** by observing the downward spike of the pattern while following the testing procedure you used for the available coil voltage test.

Turn to your Review Exercise Book and complete Exercise 9.

WORK ACTIVITIES

Before doing a work activity, make sure you've learned all the information that comes before it in the Student Guide. If you need a review, read the information on the pages listed in parentheses next to each work activity. Do not begin any of these work activities until you have your instructor's approval. If you're not sure you can do a work activity, ask your instructor for help.

1. Using the scope, analyze the secondary ignition circuit for overall performance. Check for:

- loose secondary coil wire
- open secondary circuit
- excessive resistance in the secondary circuit insulation (pages 68-75).

Record your test results.

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

2. Using the scope, analyze the available secondary coil voltage and the condition of the secondary ignition circuit insulation (pages 75-79). Record your test results.

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

After you have finished these activities, go on to the next section.

Spark Plug Firing Voltage Tests

These scope tests check on whether the voltage developed is high enough to overcome the rotor gaps and the spark plug gaps and establish a spark across the spark plug electrodes. The tests let you check on the condition of the spark plugs and the secondary circuit, cylinder temperature, fuel mixture, and cylinder compression pressures. Each of these affects the voltage required to fire the spark plugs.

To test:

STEP 1 Set the pattern selector to the display position.

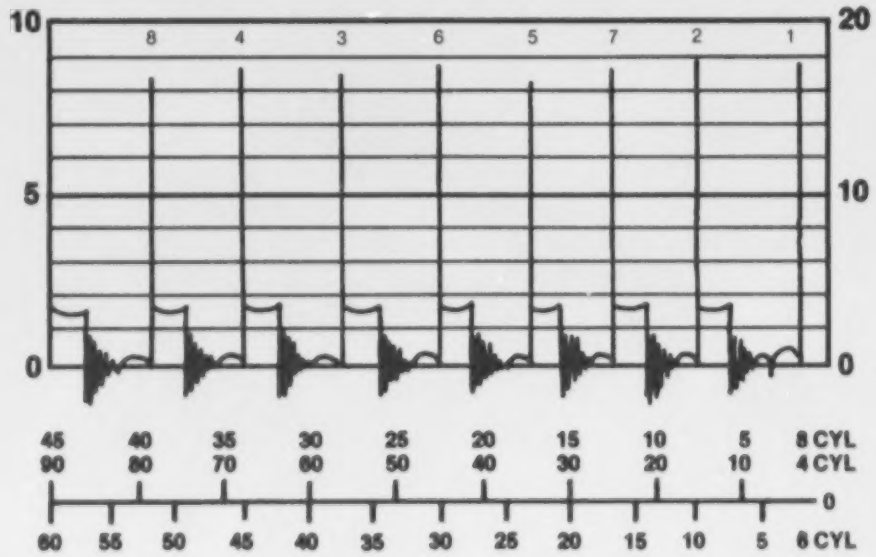
STEP 2 Turn the secondary pattern height to the 20 kv position.

STEP 3 Operate the engine at approximately 1,500 RPM.

STEP 4 Compare the firing lines of all the cylinders for height and uniformity.

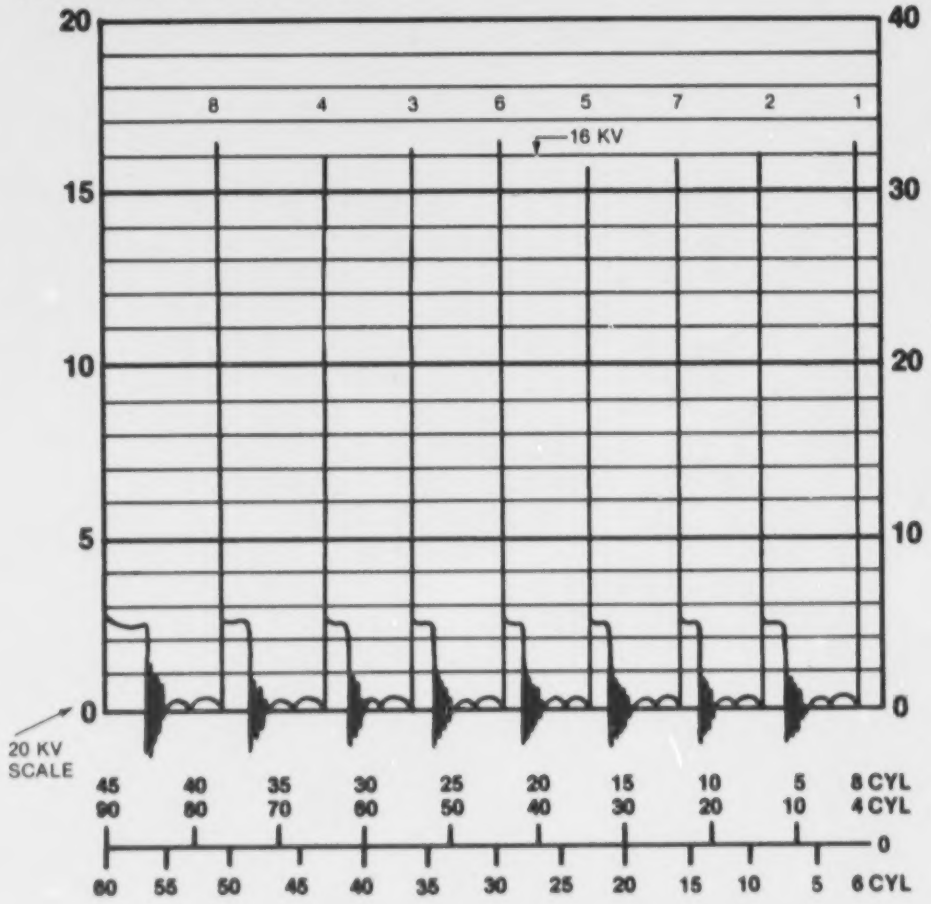
GOOD A normal display pattern is shown in figure 18-11. The normal height of the firing line should be between 5 kv and 15 kv, with no more than a 3 kv variation between cylinders.

Figure 18-11 Normal Scope Reading for Testing the Spark Plug Firing Voltage



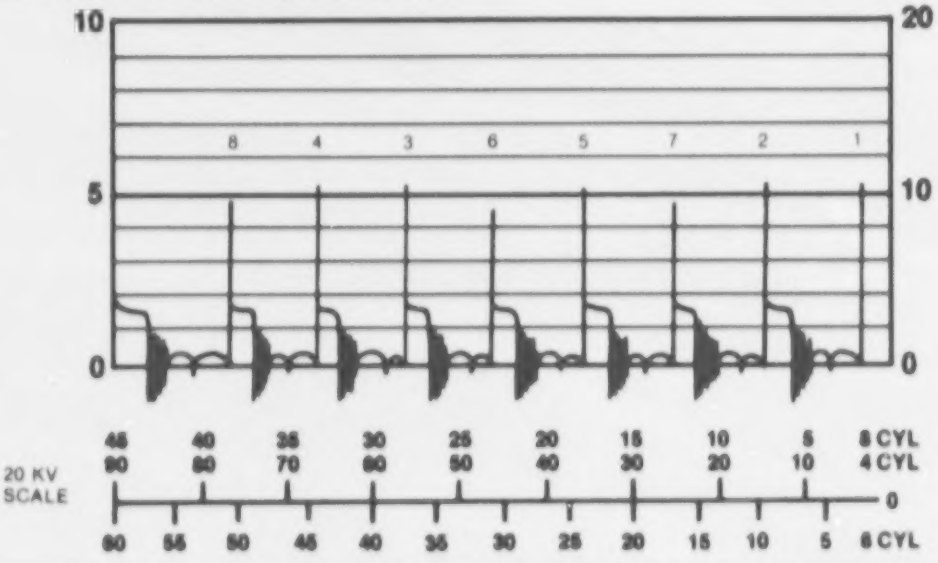
BAD All the firing lines are high. This indicates worn or widely gapped spark plugs, broken or damaged spark plug wires, too large a rotor gap, a break in the coil wire, late ignition timing, or a lean fuel mixture (see figure 18-12).

Figure 18-12 Scope Showing all Firing Lines Are High



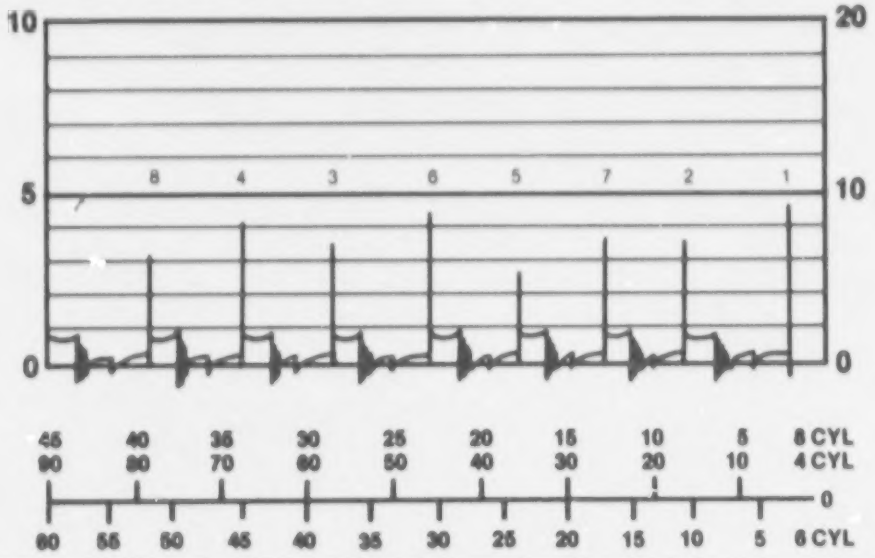
BAD All firing lines are low (see figure 18-13). This pattern indicates fouled spark plugs, narrow-gapped plugs, too rich a fuel mixture, early ignition timing, oil in the cylinders, or low compression. Each of these defects lowers the resistance in the cylinders, and the required voltage decreases accordingly.

Figure 18-13 Scope Showing all Firing Lines Are Low



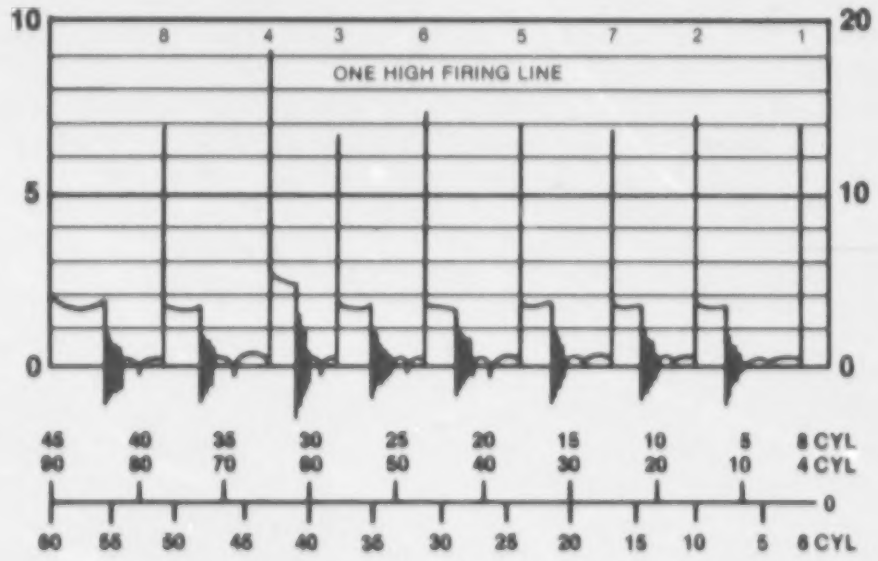
BAD Uneven firing lines (see figure 18-14). Uneven firing lines may be either abnormally high or low. This pattern indicates worn spark plugs, breaks in the spark plug wires, a cocked or worn distributor cap, or an unbalanced fuel mixture.

Figure 18-14 Scope Showing Uneven Firing Lines



BAD One high spark plug firing line. In figure 18-15, only cylinder #4 shows a high firing line. This pattern indicates a bad spark plug, a bad plug wire, or a defect in the distributor cap tower or in the cylinder.

Figure 18-15 Scope Showing One High Spark Plug Firing Line



If any of these conditions — high, low, uneven, or only one abnormal firing line — exists on the test pattern, perform the following tests to pinpoint the cause.

STEP 1 Stop the engine and install spark plug connectors between the spark plug and the leads on all the abnormal cylinders.

STEP 2 Connect a jumper lead to ground and to the large end of the resistance test contactor (probe).

STEP 3 With the engine operating at 1,000 RPM, touch the spark plug connector with the point of the resistance test contactor. Look at the firing line height.

- Required firing voltage for the cylinder being tested should now be less than 5 kv.

STEP 4 Repeat the test on all the abnormal cylinders.

- If the spike *does* fall below 5 kv, the trouble is in either the spark plug or in the cylinder. The spark plug may be worn or gapped too widely. If the plug is good, check the cylinder for carbon buildup.
- If the spike *does not* fall below 5 kv, the trouble is in the plug wire or in the distributor cap. To find out which it is, replace the suspected bad wire with a good spark plug wire. Repeat the test.
- If the spike disappears, the original plug wire is defective.
- If the high firing line is still present, the trouble is in the cap tower.

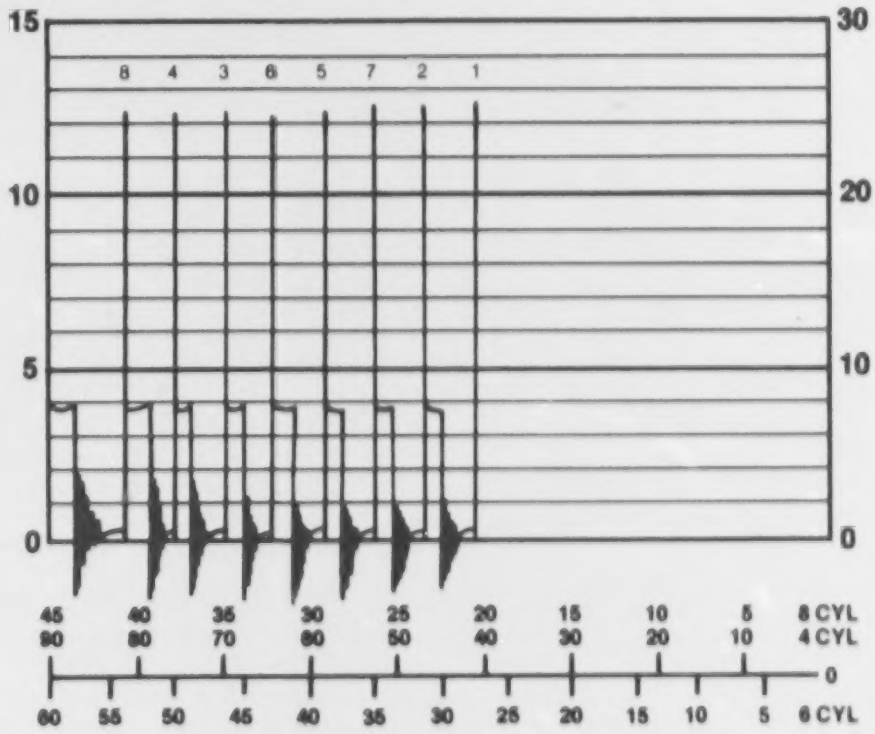
Up to this point, you have been looking at spark plug firing voltages and the firing lines of the scope patterns. In the next section, you'll learn how to recognize defective spark plugs by looking at the spark lines of the patterns. But first, you should do a ***snap load*** test when you test spark plugs.

STEP 1 With the engine idling, set the pattern selector on the display pattern at the 20 kv setting.

STEP 2 Quickly load the engine by snapping the throttle linkage and opening the throttle. Then allow the throttle to fall closed.

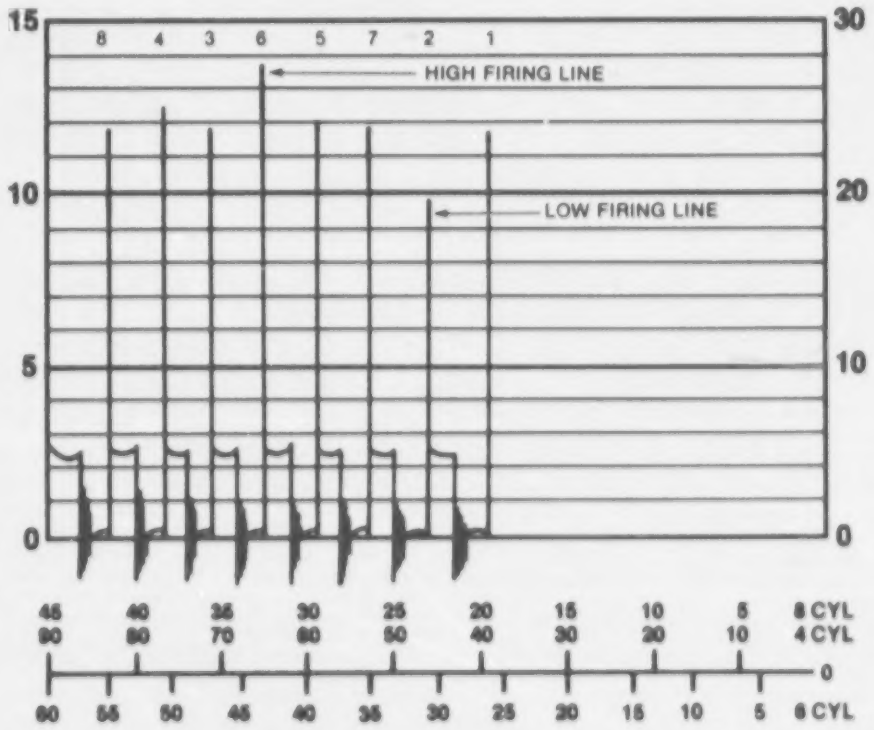
GOOD The firing lines all rise together and crowd to the left (see figure 18-16). This indicates that the engine is under snap load. As the speed of the engine increases, the required voltage will also increase.

Figure 18-16 Scope Showing Normal Firing Lines During a Snap Load Test



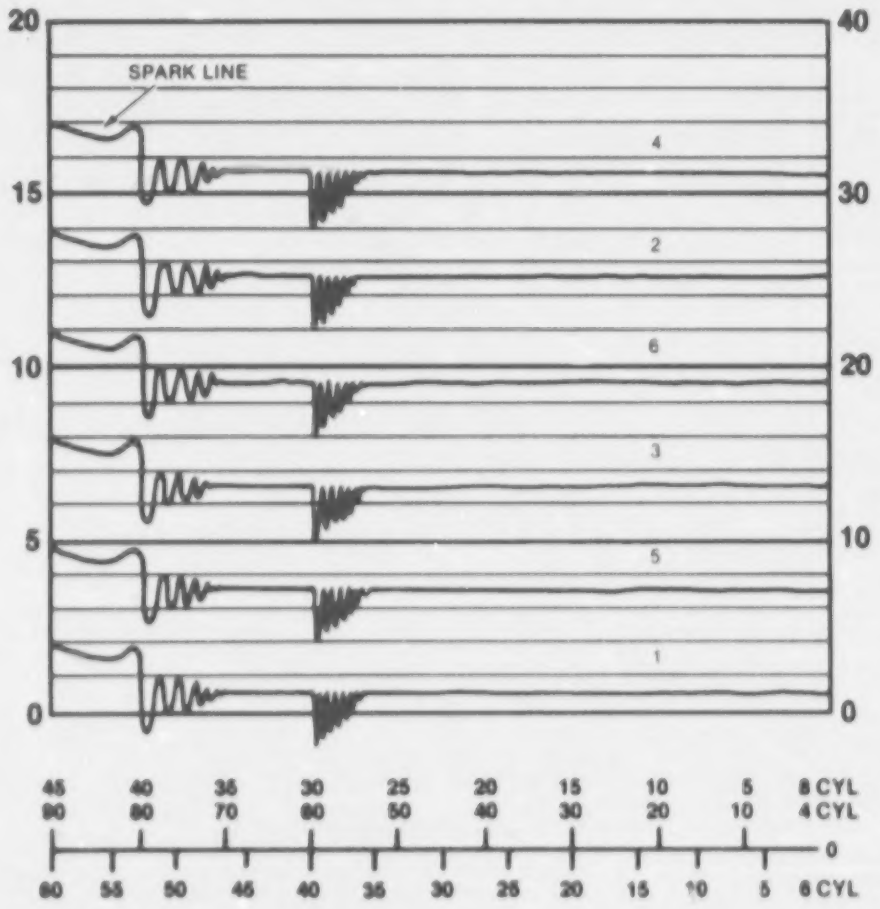
BAD One or more firing lines are high under engine load. This indicates that the spark plugs are either worn or gapped wide. In figure 18-17, cylinder #6 shows this pattern. If one or more spikes are low, the plug is gapped too narrowly, is fouling, or is flashing over. There may be oil in the cylinder, a grounded plug wire, or a cracked plug. In figure 18-17, the #2 cylinder shows this pattern. To locate the problem, replace the old spark plug wire with a good one in the cylinder that shows the low pattern.

Figure 18-17 Scope Showing a High and Low Firing Line During a Snap Load Test



- If the low spark line continues, the spark plug is defective or there is oil in the cylinder. To find the faulty spark plug, turn the pattern selector to the raster pattern. With the engine idling, look at the individual cylinder spark lines (see figure 18-18).

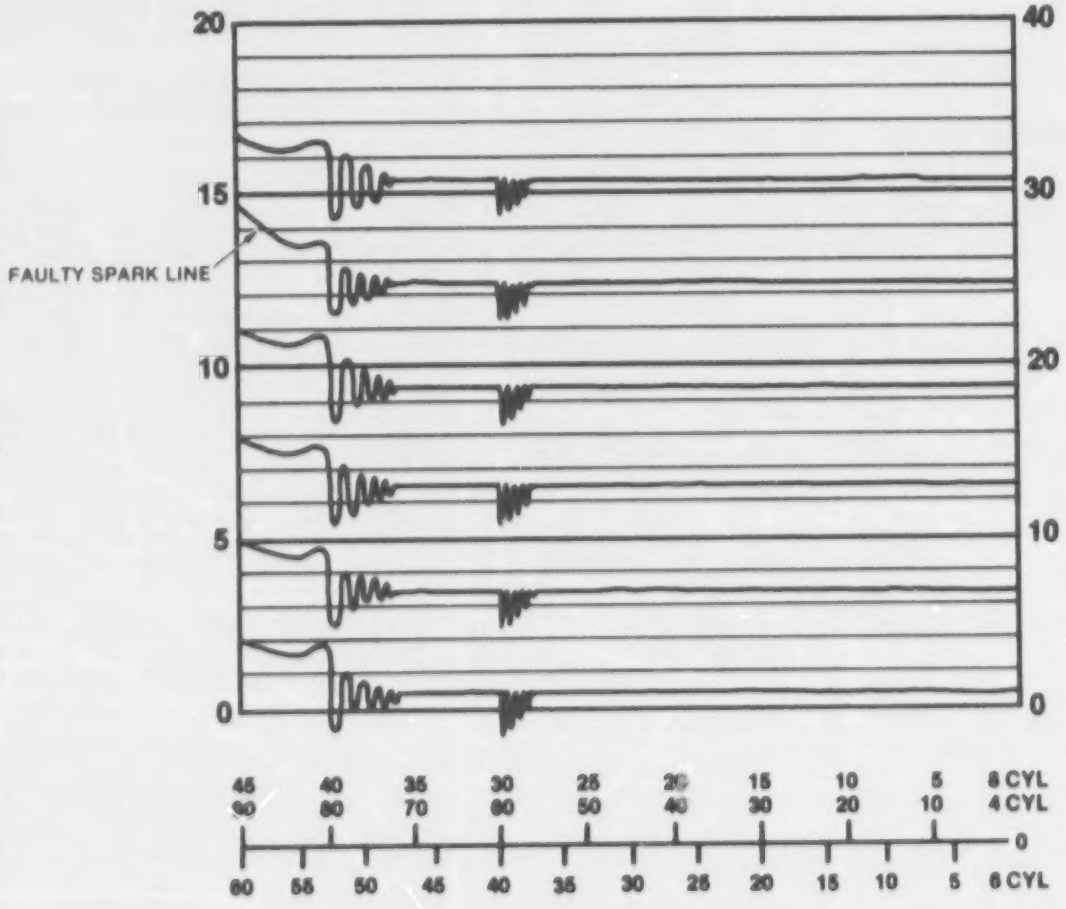
Figure 18-18 Scope Showing a Normal Raster Pattern



GOOD Figure 18-18 shows a normal raster pattern. All spark lines are uniform and nearly level.

BAD The spark line slopes excessively upward (#2 cylinder in figure 18-19). This indicates excessive resistance in the spark plug.

Figure 18-19 Scope Showing Excessive Resistance in the #2 Spark Plug

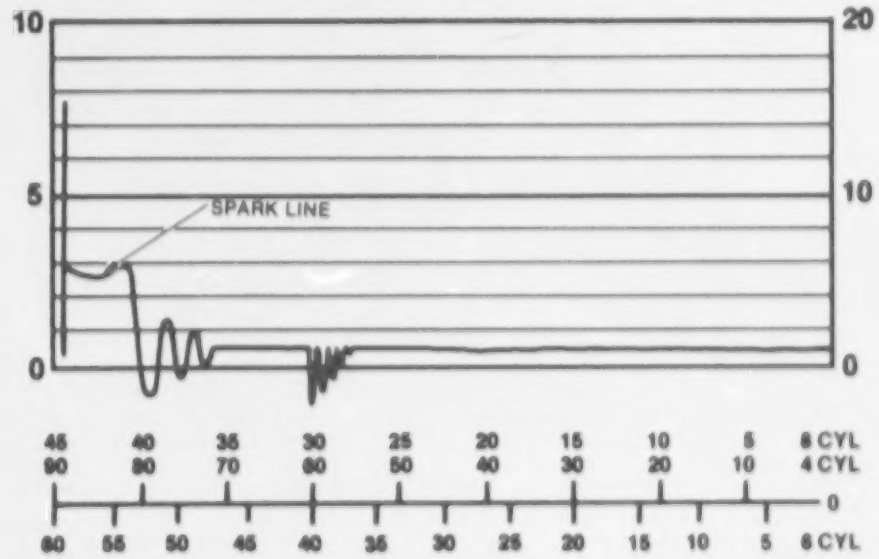


- Now turn the pattern selector to the display position and adjust the scope to pull one waveform out of the display pattern. With the engine idling, look at the firing line and compare the spark lines for further signs of defective spark plugs.

NOTE: All scopes are not alike. Therefore, you may not be able to separate the waveforms on your scope.

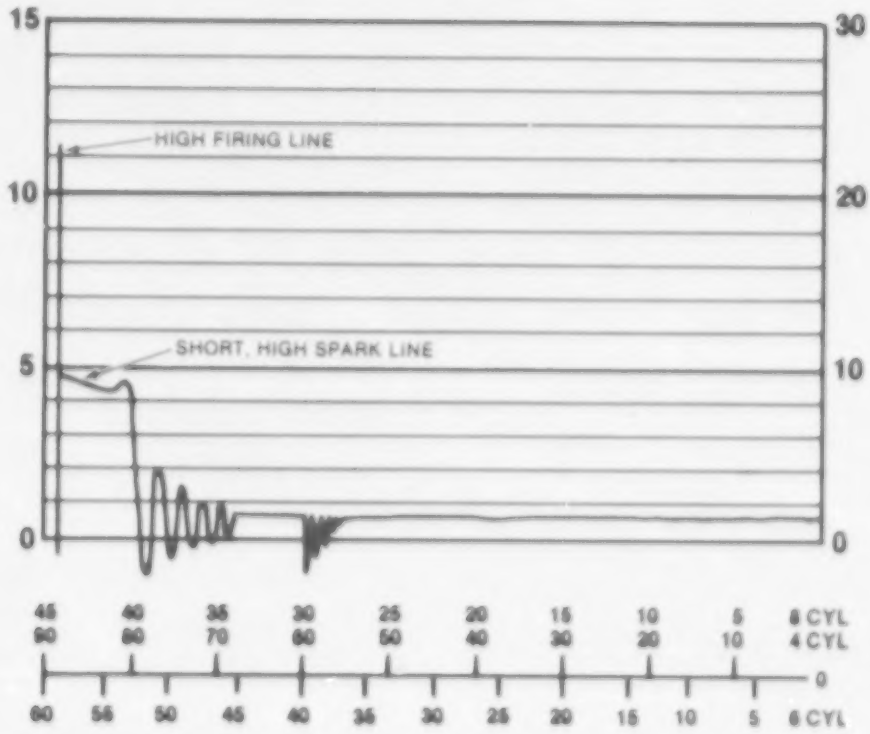
GOOD Normal signal display pattern with a uniform and nearly level spark line is shown in figure 18-20.

Figure 18-20 Normal Signal Display Pattern



BAD High firing line and a short, high spark line. This indicates a widely gapped spark plug (see figure 18-21).

Figure 18-21 Scope with High Firing Line and Short, High Spark Line



BAD A short firing line and a low spark line indicate a narrowly gapped spark plug (see figure 18-22).

Figure 18-22 Short Firing Line and Low Spark Line

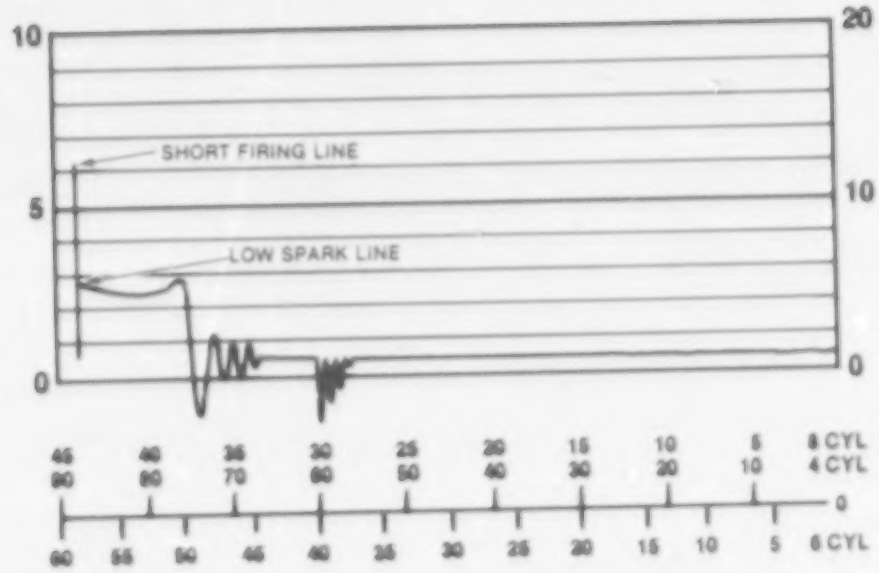


Table 18-1 *Scope Display Patterns of Spark Plug Firing Voltages*

Firing Lines	Causes
• All firing lines are high. (Normal height is between 5 kv and 15 kv, with no more than 3 kv variation between cylinders.)	• Spark plugs are too widely gapped. • Spark plugs are worn. • Spark plug wires are broken or damaged. • Rotor gap is too wide. • Coil wire is broken. • Ignition timing is late. • Fuel mixture is lean.
• All firing lines are low. (Normal height is between 5 kv and 15 kv, with no more than 3 kv variation between cylinders.)	• Spark plugs are fouled. • Spark plug gaps are too narrow. • Ignition timing is early. • Oil is in the cylinders. • Fuel mixture is too rich. • Compression is low.
• Firing lines are uneven.	• Spark plugs are worn. • Spark plug wires are broken. • Distributor cap is worn. • Fuel mixture is unbalanced.
• One firing line is high.	• Spark plug gap is too wide. • Spark plug is worn. • Spark plug wire is defective. • Distributor cap tower is defective.
• One firing line is low.	• Spark plug is fouled. • Plug insulator is cracked. • Spark plug is flashing over.

Steps to Perform When Pinpointing the Cause of Bad Firing Line(s)

STEP 1 With the engine operating at 1,000 RPM, touch each spark plug connector with the point of the resistance test contactor of the cylinders having the bad firing line(s).

STEP 2 Read the kv results.

- If the firing line falls below 5 kv, the spark plug or the cylinder is at fault.
- If the firing line does *not* fall below 5 kv, the spark plug wire or the distributor cap is at fault.
- To locate the fault, substitute a good plug wire in place of the old one and retest.
- If the firing line disappears, the original plug wire is defective.
- If the high firing line is still present, the trouble is in the cap tower.

Turn to your Review Exercise Book and complete Exercise 10.

WORK ACTIVITY

Before doing a work activity, make sure you've learned all the information that comes before it in the Student Guide. If you need a review, read the information on the pages listed in parentheses next to the work activity. Do not begin the work activity until you have your instructor's approval. If you're not sure you can do the work activity, ask your instructor for help.

3. Using the scope, analyze spark plug firing voltage performances (pages 80-94). Record your test results.

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

After you have finished this activity, go on to the next section.

Distributor Cap and Rotor Tests

When you do these few scope tests involving the distributor cap and rotor, you'll learn how to recognize a cocked distributor cap and how to recognize voltage leaks between the distributor cap and the rotor. You'll also learn how to measure the voltage that is required to jump the gap from the rotor to the distributor cap segments or terminals.

Cocked distributor cap

STEP 1 Turn the pattern selector to the display pattern position.

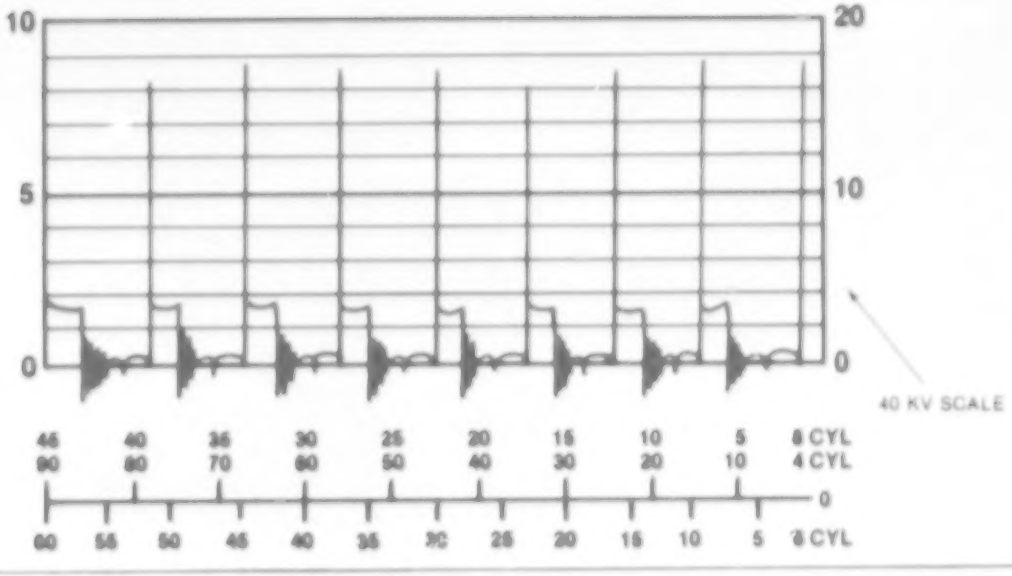
STEP 2 Turn the secondary pattern height control to the 40 kv position.

STEP 3 Operate the engine at 1,500 RPM.

STEP 4 Look at the firing lines.

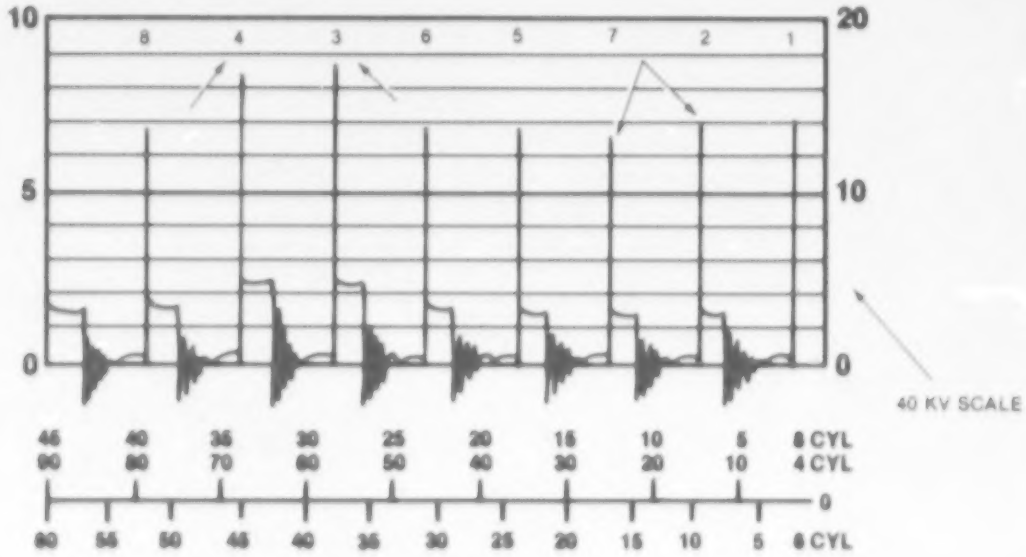
GOOD Figure 18-23 shows a normal secondary display pattern. Firing lines are normal (see figure 18-23).

Figure 18-23 Normal Secondary Display Pattern



BAD Cocked distributor cap. The pattern in figure 18-24 shows that cylinders #4 and #3 have high spikes. This shows that the rotor passed cylinders #4 and #3 at a greater distance than it did at #7 and #2, indicating that the problem is a cocked distributor cap.

Figure 18-24 Display Pattern Indicating a Cocked Distributor Cap



Distributor cap and rotor voltage leakage test

STEP 1 Continue with the same scope settings as you used for the previous test.

STEP 2 Operate the engine at 1,500 RPM.

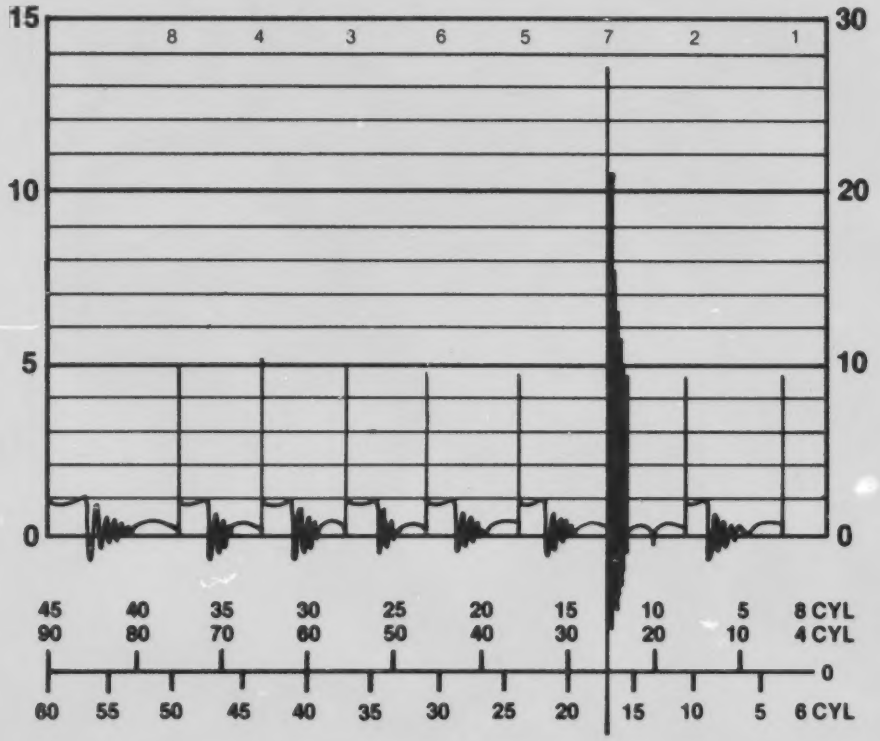
STEP 3 Remove a plug wire from the distributor cap. (You may remove any plug wire except #1 plug wire.)

STEP 4 Check the high firing line for indications of secondary leakage.

NOTE: On vehicles with catalytic converters, a spark plug wire should be removed for ***no more than 30 seconds***. During this brief time, you must also do the coil voltage output test and the rotor air gap test.

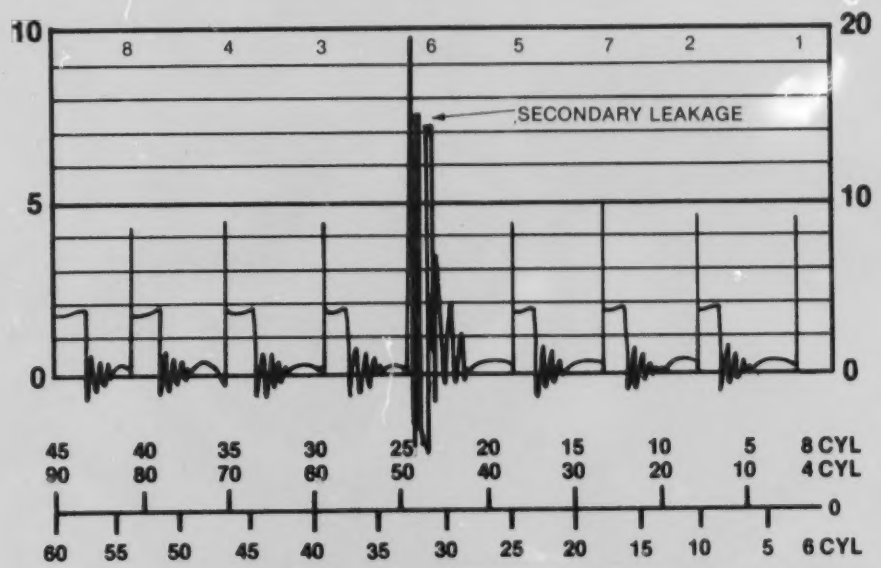
GOOD When the available coil output firing line is normal, the firing line is more than 20 kv. There are no signs of secondary leakage (see figure 18-25).

Figure 18-25 Normal Available Coil Output Firing Line



BAD Secondary leakage between the rotor and the distributor cap segment is shown in figure 18-26. The distributor cap and rotor should be replaced.

Figure 18-26 Firing Line Indicating Secondary Leakage between the Rotor and Distributor Cap



Distributor cap and rotor air gap test. This test measures the voltage required for the spark to jump the gap from the rotor to the distributor cap segments. To test:

STEP 1 Follow the same test procedures as for the distributor cap and rotor voltage leakage test. (Use the parade pattern and the 40 kv scale, and have the engine operating at 1,500 RPM.)

STEP 2 Leave the same spark plug wire disconnected from the distributor cap as you did for that test.

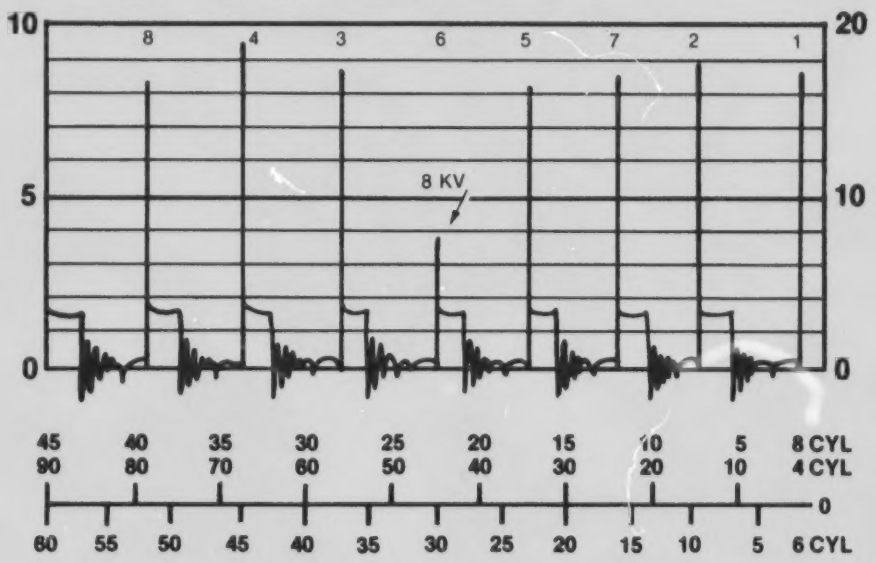
STEP 3 Clip one end of a jumper wire to ground. Then insert the probe end of the jumper wire into the vacant distributor terminal.

STEP 4 Read the kv height for the firing line of the affected cylinder.

GOOD The firing line measures less than 8 kv (see figure 18-27). This indicates that the distributor cap and rotor air gap is normal.

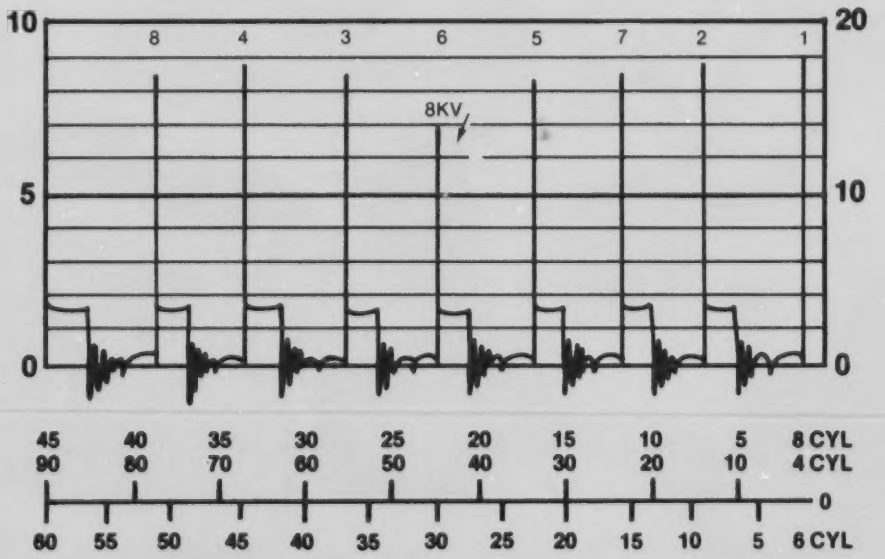
98

Figure 18-27 Normal Firing Line for Distributor Cap and Rotor Air Gap Test



BAD The firing line has dropped, but not far enough. It still reads *above* 8 kv (see figure 18-28).

Figure 18-28 Firing Line Indicating That the Cap and Rotor Must Be Replaced



- The high voltage reading indicates that the spark was forced to jump an air gap that is too wide. The cap and rotor should be replaced.
- You might check a few other terminals to see if all the results are the same. If they are, it indicates that the air gap is too wide.
- If the results are not all alike, check the condition of the terminals to be sure that good electrical contacts are made in the distributor cap.

To summarize: There are three tests you can do that indicate the condition of the distributor cap and the rotor. All three require that you observe the firing lines on the display pattern of a scope. You can:

- Check for signs of a cocked distributor cap.
- Check for signs of distributor cap and rotor voltage leakage, while one spark plug wire (other than the #1 wire) is disconnected from the distributor cap.
- Check for signs that the system is developing the proper high voltage required for the spark to jump the gap between the rotor and the distributor cap segment. One spark plug wire (other than the #1 wire) is disconnected from the distributor cap during this test.

Turn to your Review Exercise Book and complete Exercise 11.

WORK ACTIVITY

Before doing a work activity, make sure you've learned all the information that comes before it in the Student Guide. If you need a review, read the information on the pages listed in parentheses next to the work activity. Do not begin this work activity until you have your instructor's approval. If you're not sure that you can do the work activity, ask your instructor for help.

4. Using the scope, analyze and measure the distributor cap and rotor air gap voltages (pages 95-99). Record your test results.

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

After you have finished this activity, go on to the next section.

Other Scope Tests Involving the Firing Section

Over a period of time and after a great deal of practice, you'll learn about many different scope patterns that affect the different sections of the waveform. You will also develop a high degree of skill in moving your scope patterns back and forth to display patterns, raster patterns, and superimposed patterns as you search for signs of ignition malfunctions. Some bad ignition patterns are caused by engine malfunctions rather than by ignition malfunctions. Some of these engine malfunction patterns are shown below.

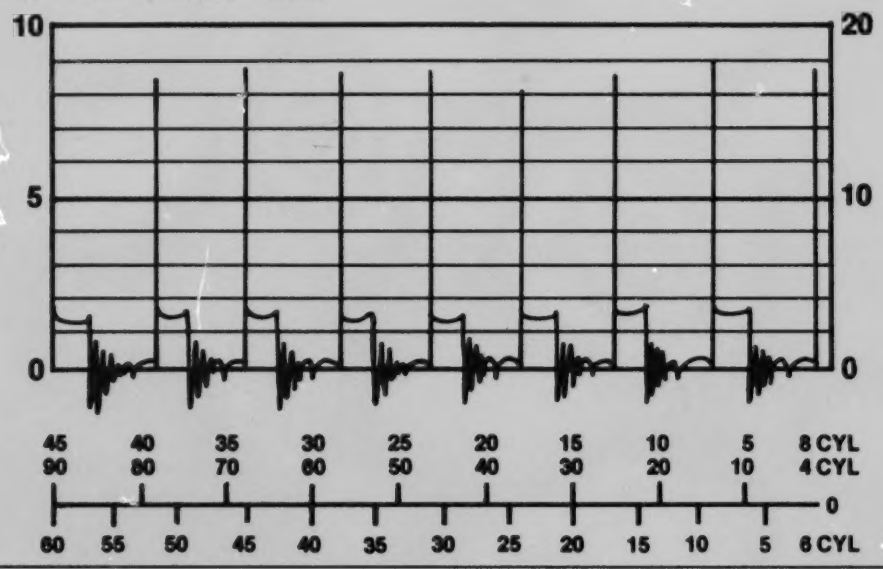
Oily Combustion Chamber

STEP 1 Operate the engine at fast idle (1,500 RPM) with the scope controls on the display pattern and the 40 kv scale.

STEP 2 Look at the spark lines.

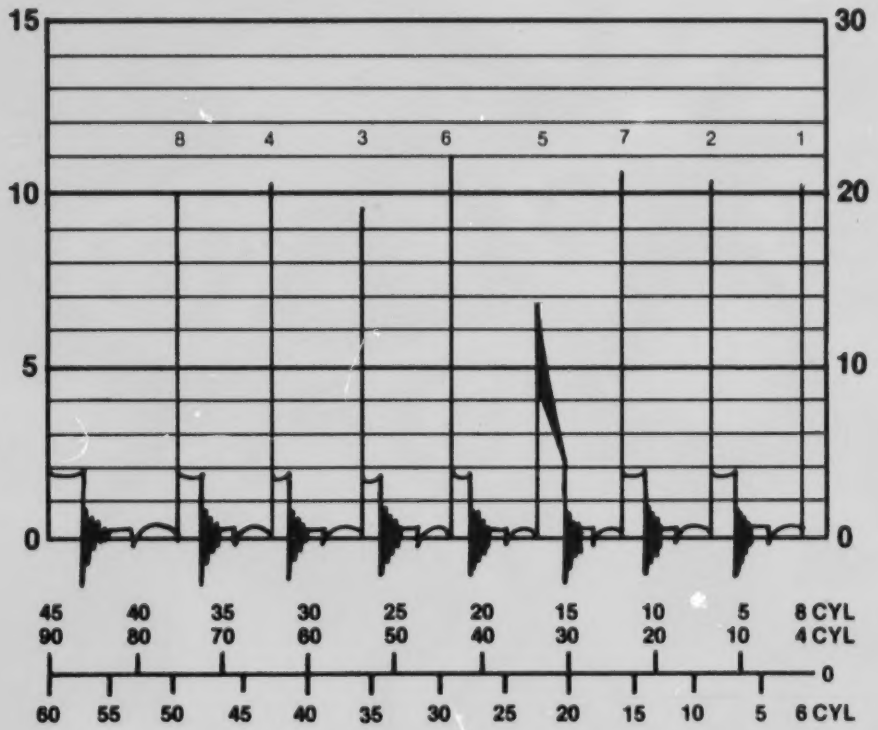
GOOD A normal secondary display pattern is shown in figure 18-29. All firing lines are at normal height.

Figure 18-29 Normal Secondary Display Patterns



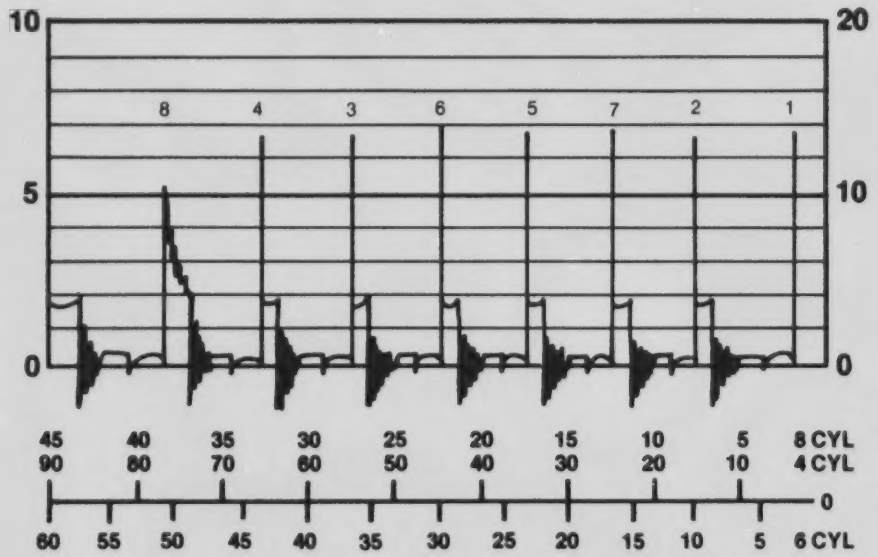
BAD The spark line begins at or near the top of the firing line and, as the short firing line spike shows, the required voltage is (usually) less than normal (#5 cylinder in figure 18-30). This indicates an oily combustion chamber.

Figure 18-30 Spark Line Indicating an Oily Combustion Chamber



BAD The spark line begins at or near the top of the firing line (#8 cylinder in figure 18-31). This pattern, which is similar to the one in figure 18-30, can also indicate a carbon-fouled spark plug.

Figure 18-31 Spark Line Indicating a Carbon-Fouled Spark Plug



Leaking Exhaust Valve

A cylinder with a leaking exhaust valve can be detected with the scope.

To test:

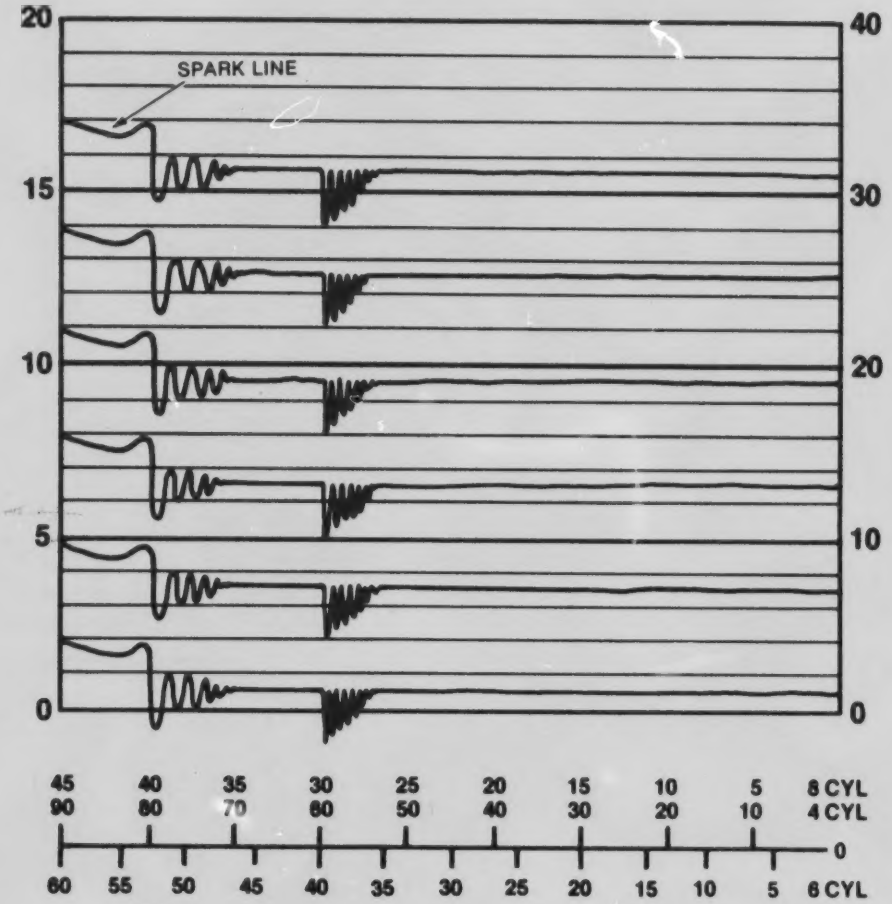
STEP 1 Switch the scope to the raster pattern.

STEP 2 Operate the engine at 1,500 RPM.

STEP 3 Watch the spark line of the pattern for a few seconds.

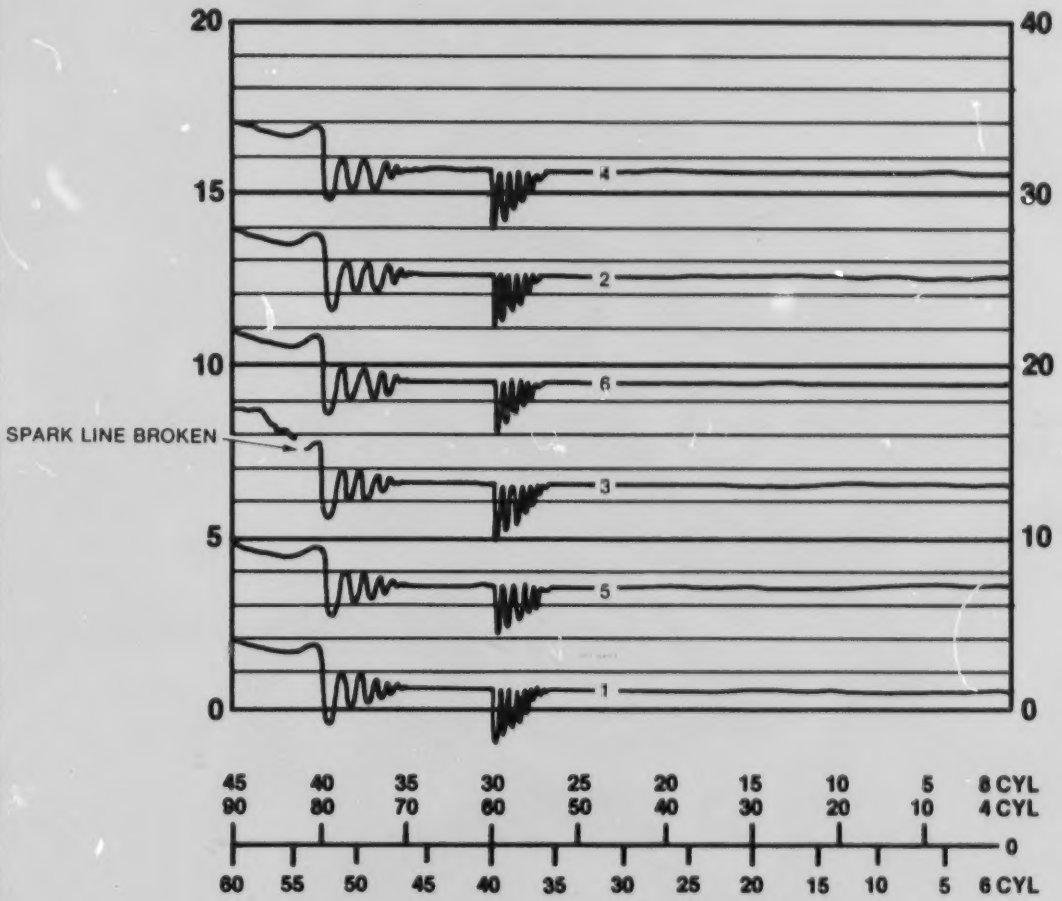
GOOD In a normal secondary raster pattern, all spark lines are uniform in length and fairly level (see figure 18-33).

Figure 18-32 Scope Showing Normal Raster Patterns



BAD A broken spark line for a cylinder (#3 cylinder in figure 18-33) indicates a leaking exhaust valve.

Figure 18-33 Raster Pattern Showing a Cylinder Has a Leaking Exhaust Valve



Fuel Starvation

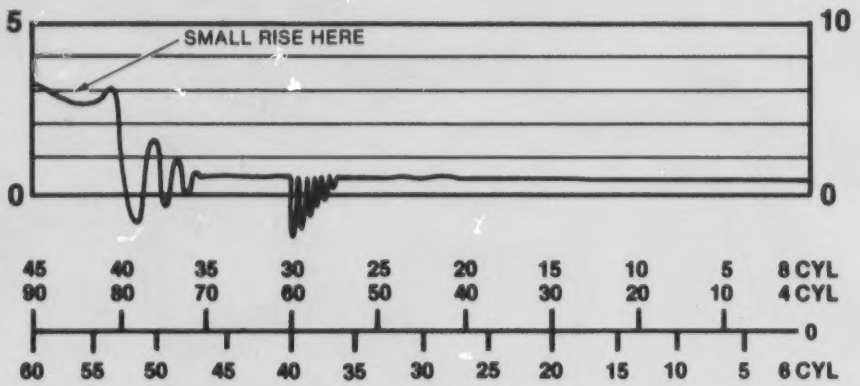
It is possible to detect signs of fuel starvation and/or retarded engine timing by watching the spark line of the firing section.

STEP 1 Switch the pattern selector to the display pattern and adjust the scope controls so that each waveform is pulled off by itself.

STEP 2 With the engine at 1,500 RPM, look closely at the spark line.

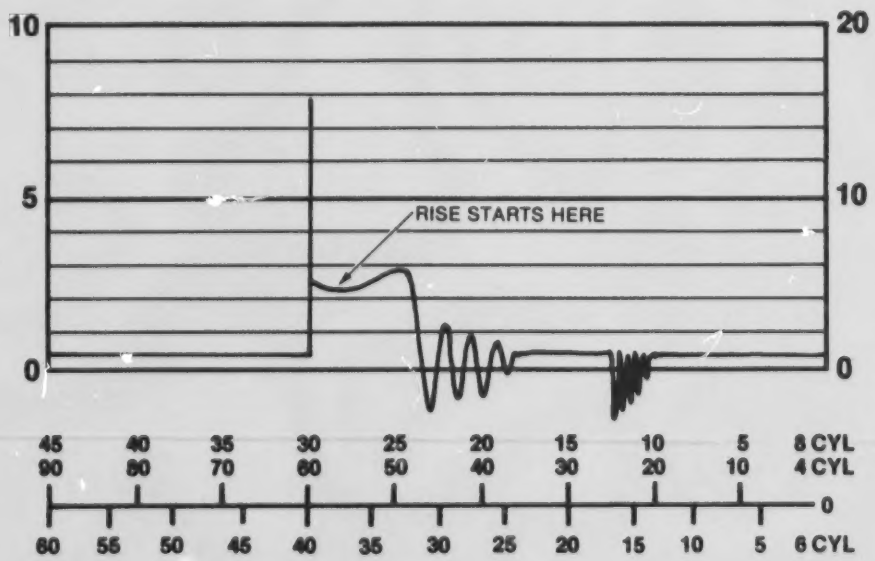
GOOD The normal spark line should have a small rise just as the intermediate section begins (see figure 18-34).

Figure 18-34 Display Pattern Showing a Normal Spark Line



BAD The spark line begins to rise midway through the line (see figure 18-35). This could be caused by fuel starvation. A float adjustment in the carburetor may be required if all the cylinders are affected.

Figure 18-35 Display Pattern Showing Signs of Fuel Starvation



- When only one cylinder shows a rise in the spark line, check for an air leak around the intake passageway for that cylinder.

NOTE: Not all scopes are alike. Therefore, you may not be able to separate the waveform on your scope.

- Retarded timing creates the same pattern as does fuel starvation. To correct retarded timing, check the engine timing, look for a rotor that is burned on one side, and adjust the carburetor float level, in that order.

Engine Adjustments

After you have done the secondary ignition tests and analyzed all your test results, it is necessary to make required minor adjustment. These adjustments should be made according to the vehicle manufacturer's procedures and specifications. In your technical service manual, look up the vehicle manufacturer's requirements by vehicle make and model for the following:

- spark plug gap specifications
- dwell adjustment
- ignition timing adjustment
- air-fuel mixture adjustment
- curb idle adjustment

Turn to your Review Exercise Book and complete Exercise 12.

WORK ACTIVITIES

Before doing a work activity, make sure you've learned all the information that comes before it in the Student Guide. If you need a review, read the information on the pages listed in parentheses next to each work activity. Do not begin the work activity until you have your instructor's approval. If you're not sure that you can do the work activity, ask your instructor for help.

5. Using the scope, analyze secondary patterns for these engine-related problems:

- oily combustion chamber or carbon-fouled spark plug
- leaking exhaust valve
- fuel starvation

Write down your test results (pages 101-107).

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

6. Perform all required minor adjustments in the engine in accordance with manufacturer's procedures and specifications. (pages 101-107).

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

When you have finished these activities ask your instructor to return your pretest on Performance Objective 18. Complete the questions that you missed or were unable to answer the first time you took the pretest. Check your answers with your instructor when you finish. Your instructor will tell you if you are ready to be checked off on the performance checklist, or if you need to correct some of your answers first.

If you are told by your instructor that you are ready for the performance checklist, carefully tear the checklist out of your Review Exercise Book and give it to your instructor.

PERFORMANCE OBJECTIVE 19

PERFORM A CYLINDER POWER BALANCE TEST

INTRODUCTION

In this performance objective, you'll learn to do a cylinder power balance test on an engine. You'll also learn how to interpret the test results, which will tell you which other tests to make in order to pinpoint a problem.

You may find it helpful to review Performance Objective 18, where you'll find information on how to hook your engine analyzer up to the engine. You may also find it helpful to review the examples of scope patterns related to ignition and engine malfunctions.

After you have finished all the activities for Performance Objective 19, your instructor will use a checklist like the one that follows to evaluate your work.

Performance Checklist—P.O. 19

Your instructor will provide either a live vehicle or live engine for this objective. Perform a cylinder power balance test on an engine. All the performances below must be accomplished.

Student Performances

1. Hooks up cylinder-balance test equipment to engine.
2. Adjusts engine idle to recommended speed.
3. Performs the cylinder balance test, and records results.
4. Interprets results, naming the cylinder(s) at fault.
5. Uses proper tools and equipment.
6. Follows appropriate safety precautions.
7. Does performance in an acceptable amount of time.

Instructor Ratings

Acceptable	Not Acceptable	Omit

SAMPLE

Tools and Equipment

You will need to use the following tools and equipment when you do work activities for Performance Objective 19. You should already be able to use a basic hand tool set, so no procedures are provided here. The procedures for using special tools and equipment will be provided as you work through the activities in this Student Guide.

Basic Hand Tool Set

Special-Purpose Hand Tools

insulated pliers (spark plug wires)

Basic Equipment

fender covers
extension light

Special Equipment

engine analyzer
tachometer
oscilloscope

Reading List

The Student Guide has been carefully designed to provide you with only the information you need to know to complete each performance objective. If you would like additional information, however, you may wish to use the references below.

General Reference

Stockel, Martin W. *Auto Service and Repair.* South Holland, Illinois: The Goodheart-Willcox Co., Inc., 1975, p. (23-7).

Special-Purpose Reference

Johnson, James A. *Automotive Diagnosis and Tune-Up.* New York: McGraw-Hill, Inc., 1972, pp. 265-67.

Personal and Service Safety Practices

Safety When Making an Electrical Test

Procedures. Follow the procedures described by the manufacturer of the electrical test equipment. This includes proper care and use of the equipment, as well as proper calibration of the equipment.

Electrical tests. Never do any electrical tests when you are standing in water or when the vehicle or engine parts are wet. A painful shock may result.

Safety When Making Ignition Tests with an Oscilloscope

Care of scope. Always keep scope leads away from fan belts and engine fan blades. Damaged scope leads are expensive to replace.

Connections. Be sure that all test leads are properly connected and comply with the equipment manufacturer's instructions.

Safety When Working around an Operating Engine

Vehicle Finish. Always use fender covers when working under the hood. This will keep fenders from getting scratched.

Personal safety. Do not reach into the engine without first looking. Your fingers could get caught in the moving parts. Serious injury may result.

Safety in Work Clothing and Grooming

Hair. Keep hair away from the moving parts of an operating engine. Keep hair under a hat if it is longer than conventional length (over your shirt collar).

Clothing. Avoid wearing loose clothing, since it can hang down and get caught in the moving parts of an operating engine. Injury can result. Loose clothing can also catch on engine parts and tear.

Jewelry. Avoid wearing any metal (rings, buckles, wristwatches, necklaces, etc.) that can come in contact with electricity. You can receive a severe burn if the metal you are wearing touches the electrical unit. Your could also damage the electrical unit.

Procedures for Doing a Cylinder Power Balance Test

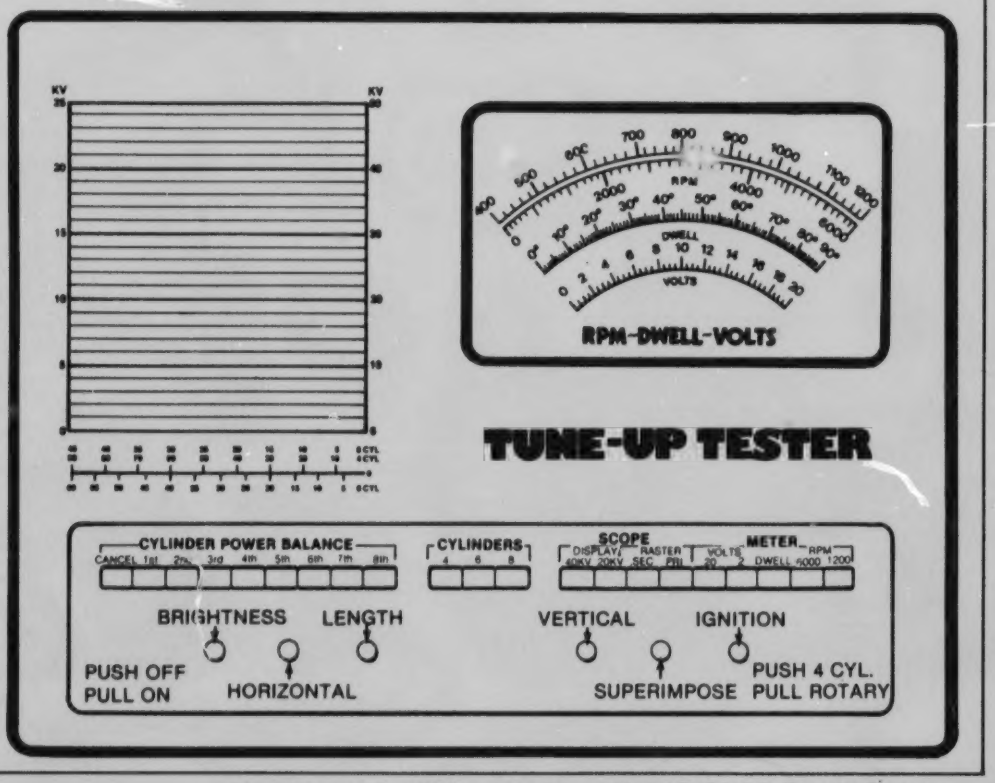
Purpose of the Test

The purpose of the cylinder power balance test is to test the power performance of each cylinder of the engine. This test determines whether all cylinders are producing equal power.

If all cylinders are not producing equal power, the test will tell if mechanical, ignition, or fuel system problems are at fault. If all cylinders are producing equal power, you can continue doing the normal tune-up procedures.

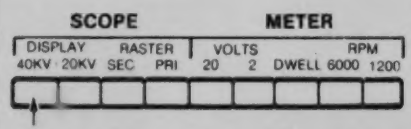
To do this test, you must prevent, one at a time, the spark plugs from firing. The main tool for this is an engine analyzer equipped with push buttons, used to short out each cylinder (see figure 19-1). You'll also use a tachometer and a scope. If an engine analyzer with a cylinder power balance tester is not available, use an adapter with each spark plug, and short out each plug with a screwdriver.

Figure 19-1 Engine Analyzer with a Cylinder Power Balance Tester



Adapted from *A Sun Performance Prover. Model TUT-915-R. Tune-Up Tester. Operating Instructions.* Used with permission of Sun Electric Corporation.

Figure 19-2 40 KV Scale on a Scope



Adapted from ***A Sun Performance Prover. Model TUT-915-R. Tune-Up Tester. Operating Instructions.*** Used with permission of Sun Electric Corporation.

The engine must be at operating temperatures when you do a cylinder power balance test.

Step-by-Step Procedures

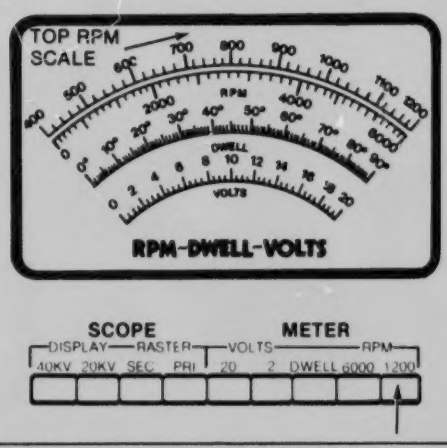
STEP 1 Hook the engine analyzer up to the engine as you did for the primary and secondary ignition scope tests.

STEP 2 Select the scope secondary display pattern and the 40 kv scale (see figure 19-2).

STEP 3 Set the RPM meter on the 1,200 scale. This means you'll be reading the top scale on the meter (see figure 19-3).

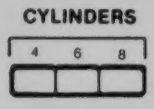
NOTE: Late model emission-controlled vehicles generally do not perform very well at low idle speed. Therefore, adjust the engine speed to between 1,000 and 1,500 RPM.

Figure 19-3 RPM Meter on the 1,200 Scale



Adapted from ***A Sun Performance Prover. Model TUT-915-R. Tune-Up Tester. Operating Instructions.*** Used with permission of Sun Electric Corporation.

Figure 19-4 Cylinder Switches

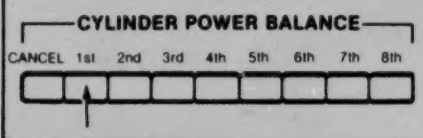


STEP 4 Set the cylinder switch on the correct number of cylinders for the engine you're testing (see figure 19-4).

STEP 5 Start the engine and let it warm up.

STEP 6 Set the engine speed so that it holds ***steady*** between 800 and 1,000 RPM. Adjust this speed by adjusting either the carburetor idle speed screw or the fast idle screw on the choke linkage. You can also use an accelerator (throttle) control tool, if one is available. Record the RPM of your setting.

Figure 19-5 Buttons Used to Short Out the Cylinders

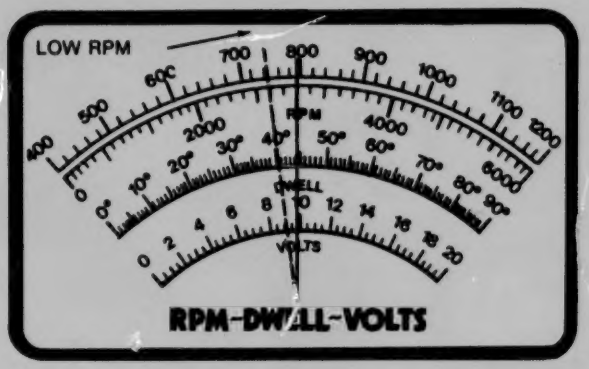


Adapted from ***A Sun Performance Prover. Model TUT-915-R. Tune-Up Tester. Operating Instructions.*** Used with permission of Sun Electric Corporation.

STEP 7 Press the first button to short out the #1 cylinder (see figure 19-5).

For example, if you started at an engine speed of 800 RPM and the shorted reading is 740 RPM (see figure 19-6), write down 740 RPM (see figure 19-7).

Figure 19-6 Example of an RPM Reading with One Cylinder Shorted Out



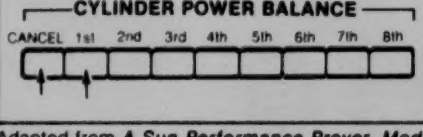
Adapted from ***A Sun Performance Prover . Model TUT-915-R. Tune-Up Tester. Operating Instructions.*** Used with permission of Sun Electric Corporation.

NOTE: The normal RPM loss is approximately 40-60 RPM for an 8-cylinder engine, 60-80 RPM for a 6-cylinder engine, and 80-100 RPM for a 4-cylinder engine. The fewer the number of cylinders, the greater the RPM loss.

Figure 19-7 Record the Reading for Each Cylinder

(800 RPM) CYL.	#1	#2	#3	#4	#5	#6	#7	#8
RECORD low RPM	740							

Figure 19-8 Press either the "Cancel" or "1st" Button To Return the Cylinder to Normal Operation



Adapted from ***A Sun Performance Prover. Model TUT-915-R. Tune-Up Tester. Operating Instructions.*** Used with permission of Sun Electric Corporation.

STEP 8 Press the "cancel button *or* press the "1st" button again to cancel out the test setting and return the cylinder to normal operation (see figure 19-8).

STEP 9 Continue to short out each cylinder in turn, repeating Steps 7 and 8. Record the low RPM reading for each cylinder as you test it.

NOTE: The push buttons are numbered in the firing order sequence of the engine.

STEP 10 Compare the low RPM readings that you recorded for all the cylinders.

- For the cylinder power balance test, look for excessive RPM variations between cylinders (see figure 19-9).

Figure 19-9 Recording RPM Test Results

(800 RPM) CYL.	#1	#2	#3	#4	#5	#6	#7	#8
RECORD low RPM	740	760	770	750	700	760	750	750

GOOD Less than 30 RPM difference between cylinders.

BAD More than 30 RPM difference between cylinders. A difference that large means that the engine develops unequal power output from the cylinders.

- In Figure 19-9, cylinder #5 recorded 700 RPM. Cylinder #3 has a reading of 770 RPM; so there's a 70 RPM variation between these cylinders. This means that there is unequal power output between these cylinders.
- Cylinder #5 should be checked further to find the faulty mechanical part.
- Some testers use a percent scale rather than RPM readings. On such meters, a variation of 3 percent or more between cylinders indicates that there is a problem in the cylinder that has the lowest percent reading. For example, if one cylinder records 4 percent and all the others record 7 percent, the problem lies with the cylinder having the lowest reading.
- There is one precaution to keep in mind when you're looking at test results for emission-controlled vehicles that use an EGR system (mainly 1973 and later). This system recirculates a small amount of the exhaust gases back into the intake manifold. If the test results are erratic on these vehicles, do the test again. But this time, disconnect and plug the vacuum line

that goes to the EGR valve. These valves will affect the cylinder balance check.

Turn to your Review Exercise Book and complete Exercise 13.

WORK ACTIVITY

Before doing a work activity, make sure you've learned all the information that comes before it in the Student Guide. If you need a review, read the information on the pages listed in parentheses next to the work activity. Do not begin the work activity until you have your instructor's approval. If you're not sure that you can do the work activity, ask your instructor for help.

1. Do a cylinder power balance test on a V-8 engine (pages 114-118). Record your test results.

After you have finished this activity, go on to the next section.

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

Meaning of Cylinder Power Balance Test Results

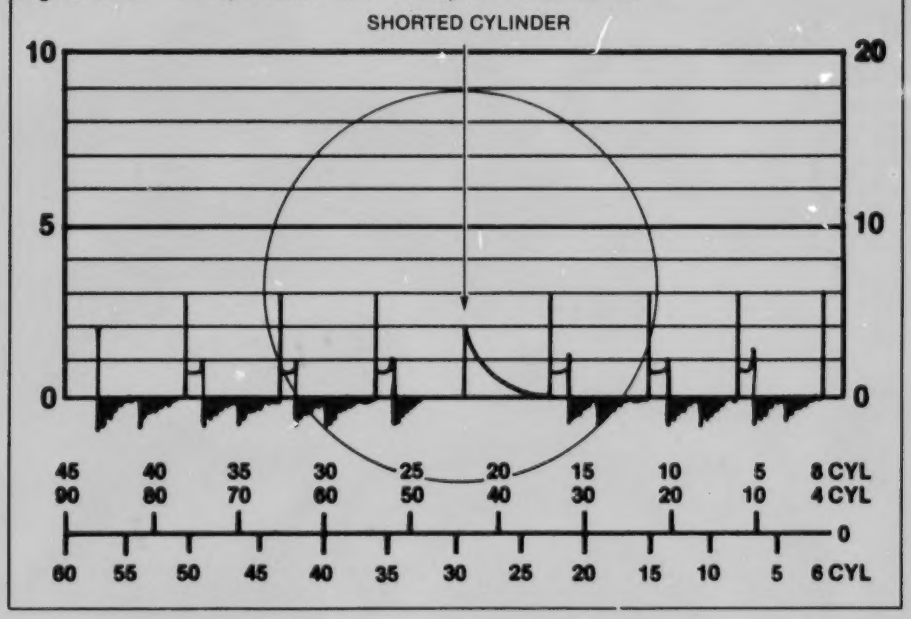
If one or more cylinders show variation readings beyond the recommended limits, check the mechanical condition of the engine. You should do a cylinder leakage test or a cylinder compression test. These two tests will tell whether the low cylinders have compression losses because of valve problems or piston ring problems. You'll learn how to do a cylinder leakage test and a compression test in this unit.

Ignition problems or fuel problems affecting combustion efficiency in the cylinder are also causes of excessive cylinder variations.

Other Tests

Since the scope is already attached to the engine when you do the cylinder power balance test, check the secondary ignition results. On any cylinder(s) that test low or show a great variation, you will want to retest and check the scope results. Look at the kv firing line while you do this test (see figure 19-10).

Figure 19-10 A Scope Pattern with One Cylinder Shorted Out



While doing a cylinder power balance test, use the scope to check the secondary ignition circuit and the spark plug firing voltages.

STEP 1 Stop the engine and install spark plug connectors between the spark plug and the leads on all the cylinders that tested low during the cylinder power balance test.

STEP 2 Connect a jumper lead to ground and to the large end of the resistance test contactor (probe).

STEP 3 With the engine running at 1,000 RPM, touch the spark plug connector with the point of the resistance test contactor. Look at the firing line height.

- The required firing voltage for the cylinder being tested should now be less than 5 k.

STEP 4 Repeat the test on all the abnormal cylinders.

NOTE: Don't forget to pull each plug's wire before you test the plug.

Table 19-1 Condition and Probable Cause of an Abnormal Firing Line Reading

CONDITION	CAUSE
1. If firing line is above 5 kv:	the spark plug wire or the distributor cap is at fault.
2. If firing line falls below 5 kv:	a fouled spark plug or a cylinder is at fault.

Study the table below, which shows the results of both the cylinder power balance tests and the scope tests.

Table 19-2 Diagnosis Chart for Cylinder Power Balance Test

CYLINDER BALANCE TEST RESULTS	SCOPE KV	PROBLEMS
1. One or more cylinders dead (no RPM drop)	High (above 5 kv)	Inspect an open spark plug wire or bad distributor cap
2. One or more cylinders dead (no RPM drop)	Low (below 5 kv)	Suspect a fouled spark plug or bad cylinder
3. One or more cylinders low	Low	Check compression
4. One or more cylinders low	High	Check for vacuum leak
5. Two adjacent cylinders dead or low	Low	Suspect a blown headgasket; check the radiator for signs of bubbling in the coolant
6. Four cylinders low. (All four cylinders use the same intake manifold passageway)	High	Suspect unbalanced carburetor or intake manifold leak

If the cylinder power balance test is still bad after you've corrected any ignition problems, you'll have to do a cylinder leakage test and/or a cylinder compression test. These tests will be described in the next few performance objectives.

Turn to your Review Exercise Book and complete Exercise 14.

WORK ACTIVITIES

Before doing a work activity, make sure you've learned all the information that comes before it in the Student Guide. If you need a review, read the information on the pages listed in parentheses next to the work activities. Do not begin any of the work activities until you have your instructor's approval. If you're not sure that you can do a work activity, ask your instructor for help.

2. Interpret the cylinder power balance test results, naming the cylinders at fault. From the test results, determine probable causes and make recommendations (pages 118-121).

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

3. Do a cylinder power balance test on a 6-cylinder engine. Write down and interpret your test results (pages 118-121).

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

When you have finished these activities, ask your instructor to return your pretest on Performance Objective 19. Complete the questions that you missed or were unable to answer the first time you took the pretest. Check your answers with your instructor when you finish. Your instructor will tell you if you are ready to be checked off on the performance checklist, or if you need to correct some of your answers first.

If you are told by your instructor that you are ready for the performance checklist, carefully tear the checklist out of your Review Exercise Book and give it to your instructor.

PERFORMANCE OBJECTIVE 20

PERFORM A CYLINDER LEAKAGE TEST

INTRODUCTION

In this performance objective, you'll read about the way to perform a cylinder leakage test on an engine. You'll also read about the correct way to interpret the test results. The results of this test will tell you which mechanical engine parts are at fault.

You may find it helpful to review Performance Objective 17, where you'll find information on removing and installing spark plugs.

After you have finished all the activities for Performance Objective 20, your instructor will use a checklist like the one that follows to evaluate your work.

Performance Checklist—P.O. 20

Your instructor will provide either a live vehicle or live engine for this objective. Perform a cylinder leakage test on the engine. All of the performances below must be accomplished.

Student Performances

1. Removes spark plugs, air cleaner, crankcase oil filler cap, and radiator cap.
2. Sets carburetor throttle valve in wide-open position.
3. Disables ignition system.
4. Uses remote starter switch and whistle to set #1 cylinder to TDC.
5. Installs TDC indicator, makes reference mark, and attaches indicator light.
6. Connects leakage tester, and records results; listens for escaping air.
7. Repeats test for all cylinders.
8. Interprets results, noting faulty cylinder(s).
9. Removes test equipment, installs all removed parts, and attaches all wires.
10. Uses proper tools and equipment.
11. Follows all appropriate safety precautions.
12. Does performance in an acceptable amount of time.

Instructor Ratings

Acceptable	Not Acceptable	Omit

SAMPLE

Tools and Equipment

You will need to use the following tools and equipment when you do work activities for Performance Objective 20. You should already be able to use a basic hand tool set; so no procedures are provided here. The procedures for using special tools and equipment will be provided as you work through the activities in this Student Guide.

Basic Hand Tool Set

Special-Purpose Hand Tools

insulated pliers (spark plug leads)
spark plug sockets

Safety Equipment

eye protection

Basic Equipment

fender covers
extension light
compressed air hose
compressed air gun
remote control starter switch

Special Equipment

cylinder leakage tester

Reading List

The Student Guide has been carefully designed to provide you with only the information you need to know to complete each performance objective. If you would like additional information, however, you may wish to use the references below.

General References

Crouse, William H. *The Auto Book.* New York: McGraw-Hill, Inc., 1974, pp. 338-339.

Crouse, William H. *Automotive Mechanics.* 7th ed. New York: McGraw-Hill, Inc., 1975, p. 418.

Ellinger, Herbert E. *Automechanics.* 2nd ed. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1977, p. 252.

Stockel, Martin W. *Auto Service and Repair.* South Holland, Illinois: The Goodheart-Willcox Co., Inc., 1975, pp. (23-24) - (23-25).

Special-Purpose Reference

Wetzel, Guy F. *Automotive Diagnosis and Tune-Up.* 6th ed. Bloomington, Illinois: McKnight Publishing Co., 1974, pp. 89-90.

Personal and Service Safety Practices

Safety When Working around Spark Plugs

Vehicle finish. Always use fender covers when working under the hood to prevent the fenders from getting scratched.

Procedures. Follow correct procedures when disconnecting spark plug wires. This will prevent stretching and possibly breaking spark plug wires unnecessarily.

Always follow correct procedures and use the right tools when removing, gapping, and installing spark plugs. This will prevent damaging or breaking spark plugs, making them unserviceable.

Care of eyes. Always wear eye protection equipment when using compressed air to blow dirt from around the spark plugs and when sandblasting spark plugs. This will prevent dirt and other debris from getting into your eyes.

Safety Requirements When Working with Hydraulic Equipment

You may find it easier to remove and install spark plugs on some engines from under the vehicle. If you can easily get to the plugs without lifting the vehicle, the following safety practices do not apply.

Hydraulic floor jacks and jack stands

- Place the jack securely under the vehicle frame.
- Slowly raise the vehicle with the jack.
- Always support the vehicle by placing the jack stand in a secure position under the vehicle.
- Store the jack handle. Do not leave it on the floor where someone could trip over it.

Hydraulic lift equipment

- Never put more weight on the lift than its rated capacity. (You'll find the lift's rated capacity on the lift.)
- Never rock the vehicle while it is on the lift.

- Always be sure the vehicle is securely on the lift before you raise the lift.

Safety When Making Cylinder Leakage Tests

Procedures. Always follow the cylinder leakage tester manufacturer's instructions. This will keep you from damaging the equipment or receiving incorrect test readings.

Personal safety. Always follow safety precautions when you use compressed air. Wear eye protection, and be sure all compressed air fittings are tightly joined. These precautions will keep you from accidentally getting dirt in your eyes or incorrect test results.

Safety in Work Clothing and Grooming

Clothing. Avoid wearing loose clothing, which can hang down and get caught in the moving parts of an operating engine. Injury can result. Loose clothing can also catch on engine parts and tear.

Hair. Keep hair away from moving parts of an operating engine. Keep your hair under a hat if your hair is longer than conventional length (over your shirt collar).

Procedures for Doing a Cylinder Leakage Test

Purpose of a Cylinder Leakage Test

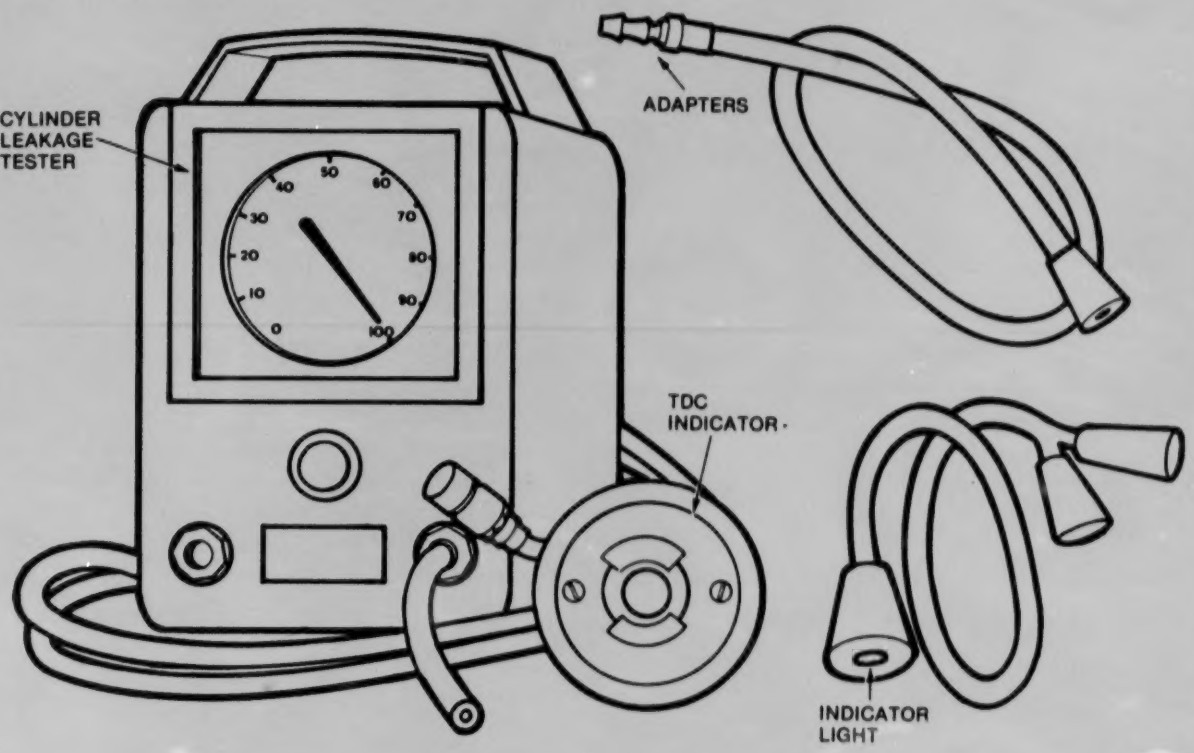
In this section, you'll read about the way to use a cylinder leakage tester (CLT) to check a bad engine condition (see figure 20-1). You'll use this tester directly after a cylinder power balance test in which one or more cylinders either showed an excessive drop in RPM or varied quite noticeably from the other cylinders. Those results tell you that, on those cylinders, the fault is mechanical and lies within the engine. You'll want to pinpoint the troublesome part.

The cylinder leakage tester locates compression losses in an engine. Compression losses/leaks occur at the intake and exhaust valves, at the head gaskets, or at the piston rings. The cylinder leakage tester will tell which part or parts are at fault.

Briefly, the test works like this:

- Air pressure is forced into the cylinder when the piston is at top dead center (TDC).
- The piston must be on the compression stroke. Both intake and exhaust valves must be closed.
- No air should escape from a good cylinder. However, in practice it is normal for a small amount of air to escape past the rings and into the crankcase.

Figure 20-1 Cylinder Leakage Tester



Calibrating the Tester

Always follow the tester manufacturer's directions in both the use and calibration of the tester.

If the tester isn't properly calibrated, you can get a misreading and possibly give out the wrong information about what's at fault.

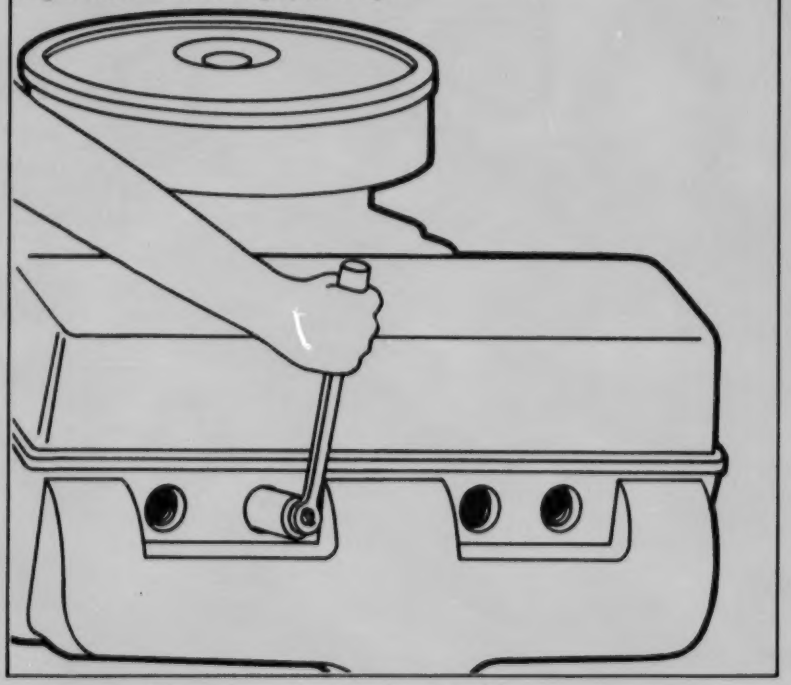
See your instructor for the operating instructions for the cylinder leakage tester you will use. Then, check, adjust, and calibrate the tester following the manufacturer's recommendations.

Step-by-Step Procedures

The engine must be at normal operating temperatures before you do the leakage test.

STEP 1 Remove all the spark plugs from the cylinders (see figure 20-2). You may need to test all cylinders or only those cylinders that indicated a problem during the cylinder power balance test.

Figure 20-2 Removing Spark Plugs



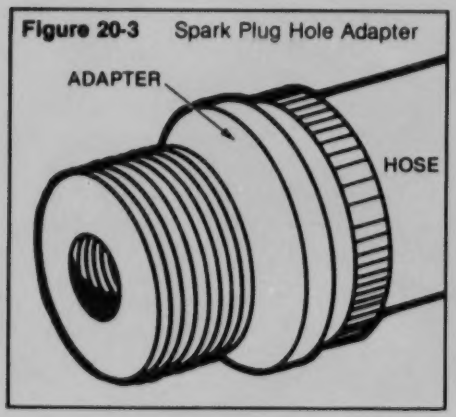
Be sure you follow proper procedures for removing spark plugs.

STEP 2 Remove the radiator cap, the oil filler cap, and the carburetor air cleaner. Set the carburetor throttle valve in wide-open position.

STEP 3 Connect the remote starter switch to the solenoid or starter relay. Remove the coil high-tension lead from the distributor cap and ground the ignition system.

STEP 4 Select a spark plug hole adapter of the correct size from the selection furnished with the tester.

Figure 20-3 Spark Plug Hole Adapter



These adapters are threaded and plug-like, and each is fitted with a short length of air hose (see figure 20-3).

STEP 5 Install the adapter and hose into the #1 cylinder until it is finger-tight (see figure 20-4). Then put the whistle that comes with the tester into the other end of the hose (see figure 20-5).

Figure 20-4 Installing the Adapter and Hose into a Spark Plug Hole

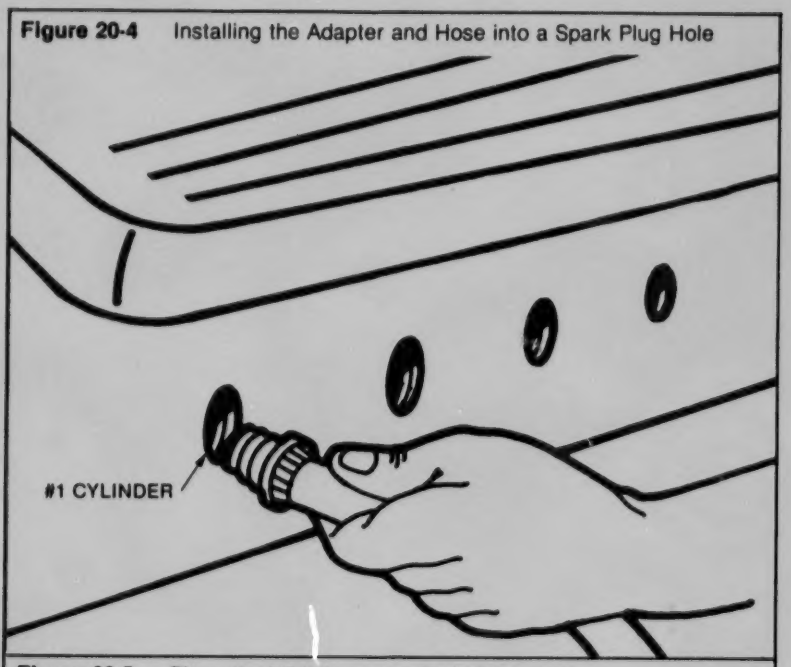
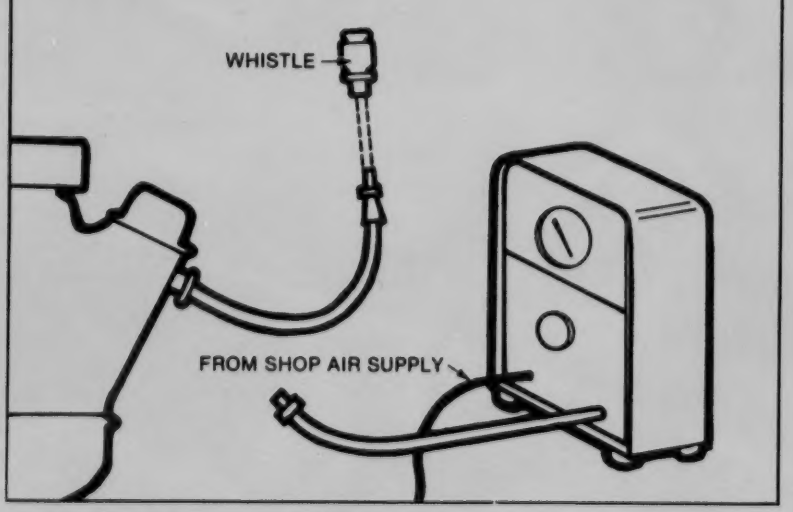


Figure 20-5 Place the Whistle on the End of the Hose



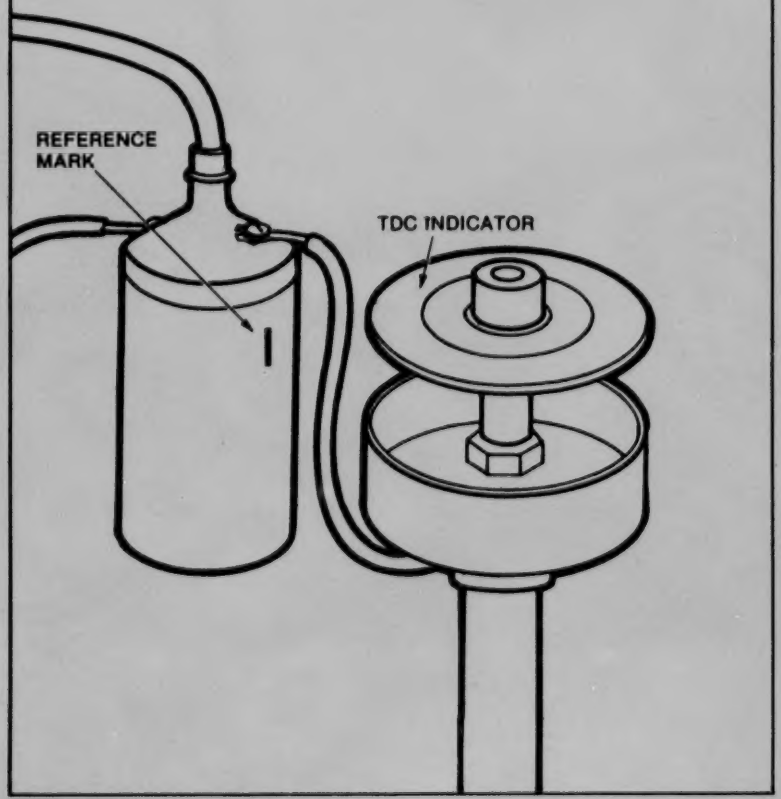
STEP 6 Crank the engine slowly until the whistle stops sounding. When the whistle stops, the piston is at top dead center (TDC) and both valves are closed. Look at the engine timing marks. The TDC engine timing mark should align with the engine timing pointer. If it doesn't, slowly rotate the engine crankshaft until they do align. Then remove the whistle.

NOTE: Be sure you follow Step 6 exactly, because if the piston is not at TDC, you'll force it down into the cylinder when you apply the air pressure.

STEP 7 Remove the distributor cap from the distributor. Mount the TDC indicator on top of the distributor shaft or rotor (see figure 20-6).

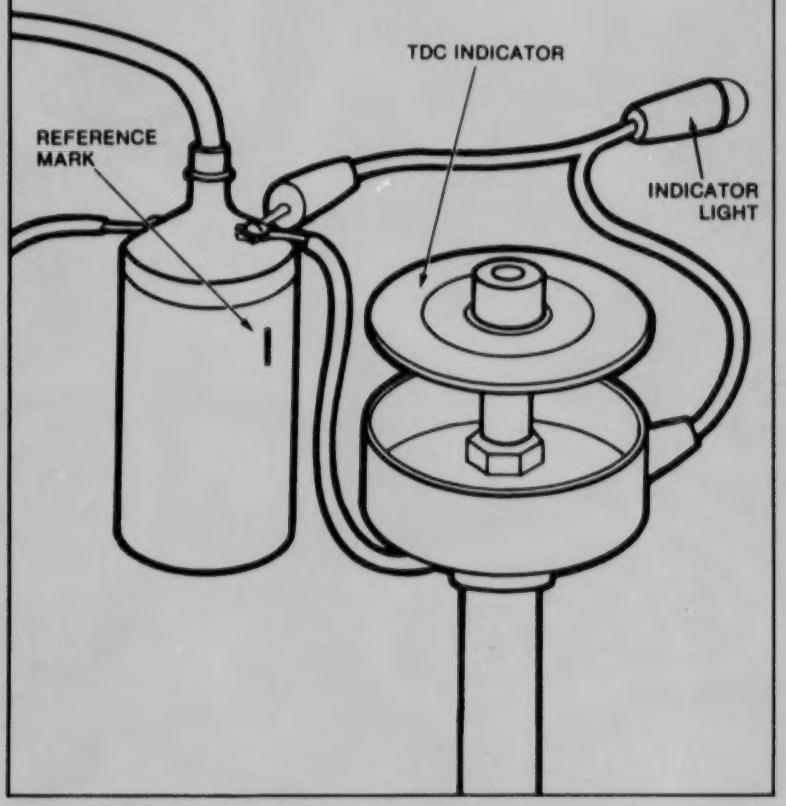
STEP 8 Chalk-mark a reference point on the engine, the coil, or some other surface that will align with an applicable mark on the TDC indicator (see figure 20-6).

Figure 20-6 Example of a TDC Indicator Installation



STEP 9 Connect the indicator light by attaching one lead to the distributor primary terminal and the other lead to ground (see figure 20-7). Turn the ignition switch on; the indicator light should go on.

Figure 20-7 Example of a TDC Indicator Installation with Light Attached



STEP 10 Connect the cylinder leakage tester hose to the hose on the spark plug adapter (see figure 20-8).

NOTE: The tester will have between 70 and 170 psi of air pressure, supplied from the shop air compressor source. This pressure is, in turn, directed into the cylinder.

CAUTION: Do not attempt to crank the engine while the tester hose is connected. If the crankshaft turns, disconnect the tester hose, install the whistle to the adapter hose, and start over again!

Figure 20-8 Connecting the Cylinder Leakage Tester Hose to the Spark Plug Adapter Hose

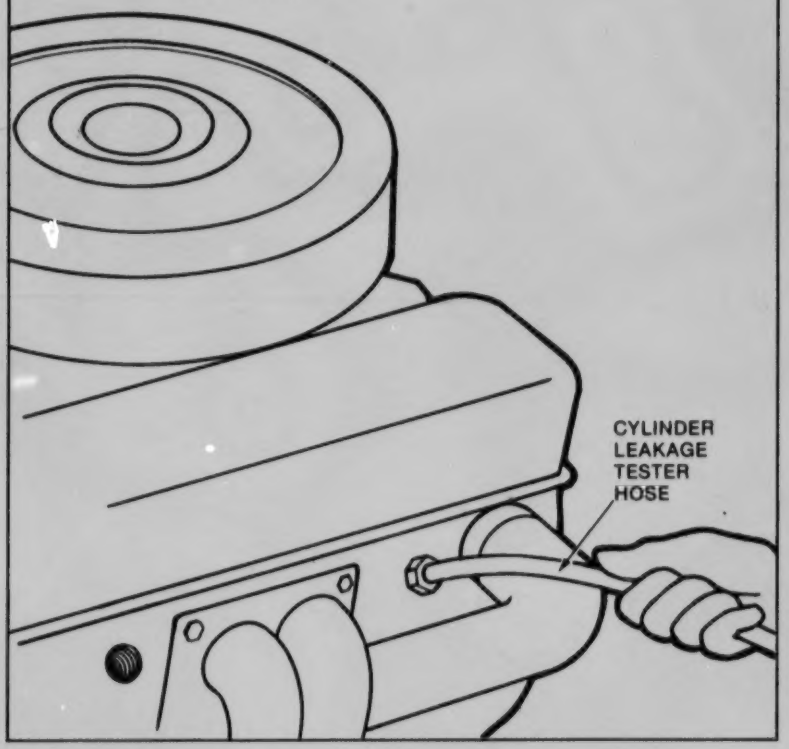
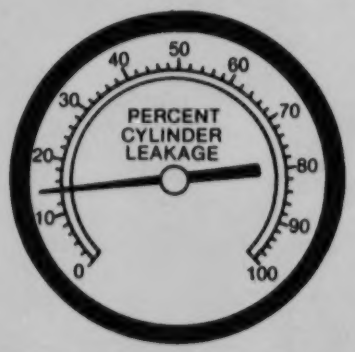


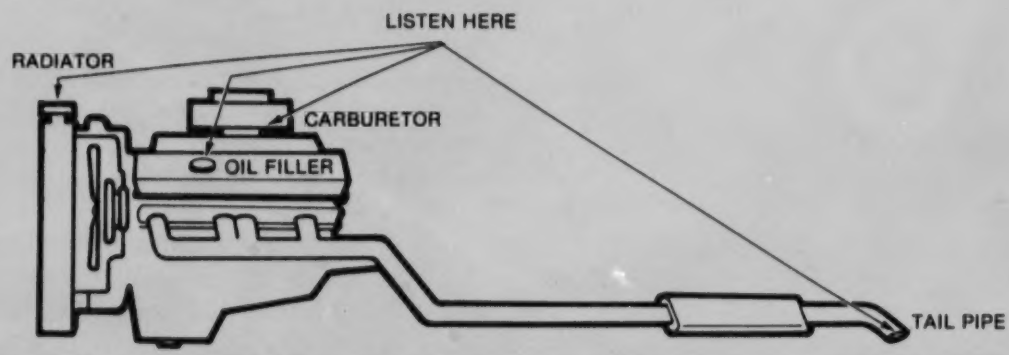
Figure 20-9 Tester Gauge Showing the Percent of Cylinder Leakage



STEP 11 Look at the tester gauge and read the "percent of cylinder leakage" (see figure 20-9). Record the reading.

At the same time, listen for air leakage from the tail pipe, the radiator, the oil filler, the carburetor, and the cylinder(s) next to the one being tested (see figure 20-10).

Figure 20-10 Points to Check for Air Leakage



GOOD The leakage reading is less than 20 percent. There is no air leak heard from the exhaust pipe, the radiator, the oil filler, the carburetor, or the nearby cylinders.

BAD The leakage reading is more than 20 percent. An air leak is heard from the exhaust pipe, the radiator, the oil filler, the carburetor, or the nearby cylinders.

Interpreting the Test Results

The sound of air leaking from one or more of the engine openings should tell you which engine parts are affected. Use the following as a guide:

- Air escaping at the carburetor tells you that the leak is at the intake valve and indicates a bad valve and the need for valve services.
- Air escaping at the tail pipe tells you that the leak is at the exhaust valve and indicates a bad valve and the need for valve services.
- Air escaping at the radiator filler cap tells you that air is leaking into the cooling system, indicating a blown head gasket or cracked head.
- Air escaping from the cylinders next to the one you are testing tells you that the leak is located between the cylinders, indicating a blown head gasket or cracked head.
- Air escaping at the oil filler tells you that the leak is in the cylinder. The leak indicates bad piston rings. If the tester gauge shows more than 20 percent leakage and no air leakage is heard past the valves or head gasket, the sound of escaping air indicates piston ring clearance.

Completing the Cylinder Leakage Tests

STEP 1 To test the next cylinder, first disconnect the tester hose from the adapter. Then rotate the engine crankshaft until the next applicable mark on the TDC indicator aligns with the chalk mark on the engine.

STEP 2 Recheck the tester calibration.

NOTE: The indicator light will glow when the piston is in firing position at TDC.

STEP 3 Remove the adapter from the cylinder just tested and install it in the cylinder next ***in the engine's firing order.*** Read the leakage results from the tester gauge.

STEP 4 Repeat Steps 1 and 2 when testing each cylinder.

STEP 5 Remove the adapter and its hose from the last cylinder tested. Disconnect the shop air hose from the cylinder leakage tester.

STEP 6 Remove the remote starter switch.

STEP 7 Remove the TDC indicator from the distributor and disconnect the indicator light. Reinstall the rotor if it was removed, and put the distributor cap back on.

STEP 8 Reconnect the coil high-tension lead. Reinstall the spark plugs, the radiator and oil filler caps, and the carburetor air cleaner.

Turn to your Review Exercise Book and complete Exercise 15.

WORK ACTIVITIES

Before doing a work activity, make sure you've learned all the information that comes before it in the Student Guide. If you need a review, read the information on the pages listed in parentheses next to the work activities. Do not begin any of the work activities until you have your instructor's approval. If you're not sure that you can do a work activity, ask your instructor for help.

1. Do a cylinder leakage test on a V-8 engine suspected of having a faulty cylinder (pages 128-136). Write down the test gauge reading.

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

2. Diagnose the defective part in a faulty cylinder (pages 135-136).

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

When you have finished these activities, ask your instructor to return your pretest on Performance Objective 20. Complete the questions that you missed or were unable to answer the first time you took the pretest. Check your answers with your instructor when you finish. Your instructor will tell you if you are ready to be checked off on the performance checklist, or if you need to correct some of your answers first.

If you are told by your instructor that you are ready for the performance checklist, carefully tear the checklist out of your Review Exercise Book and give it to your instructor.

PERFORMANCE OBJECTIVE 21

PERFORM A CYLINDER COMPRESSION TEST

137134

INTRODUCTION

In this performance objective you'll read about how to do a cylinder compression test on an engine. You'll also find out how to interpret the test results and know which mechanical engine parts are at fault.

You may find it helpful to review Performance Objective 17, where you'll find information about removing and installing spark plugs.

After you have finished all the activities for Performance Objective 21, your instructor will use a checklist like the one that follows to evaluate your work.

Performance Checklist—P.O. 21

Your instructor will provide either a live vehicle or live engine for this objective. Perform a cylinder compression test on an engine. All of the performances below must be accomplished.

Student Performances	Instructor Ratings		
	Acceptable	Not Acceptable	Omit
1. Removes all spark plugs.			
2. Removes air cleaner and sets the carburetor throttle in wide-open position.			
3. Disables the ignition.			
4. Attaches the remote starter switch.			
5. Inserts compression gauge and cranks engine four or five times; records results.			
6. Repeats Performance 5 (above) for all cylinders.			
7. Performs wet compression test(s) as necessary.			
8. Interprets results, noting defective cylinder(s).			
9. Removes test equipment, installs all removed parts, and unblocks the throttle.			
10. Uses correct tools and equipment.			
11. Follows all appropriate safety precautions.			
12. Does performance in an acceptable amount of time.			

SAMPLE

Tools and Equipment

You will need to use the following tools and equipment when you do work activities for Performance Objective 21. You should already be able to use a basic hand tool set; so no procedures are provided here. The procedures for using special tools and equipment will be provided as you work through the activities in the Student Guide.

Basic Hand Tool Set

Special-Purpose Tools

insulated pliers (spark plug leads)
spark plug sockets

Safety Equipment

eye protection

Basic Equipment

fender covers
extension light
compressed air hose
compressed air gun

Special Equipment

remote starter switch control
compression

Reading List

The Student Guide has been carefully designed to provide you with only the information you need to know to complete each performance objective. If you would like additional information, however, you may wish to use the references below.

General References

Crouse, William H. *The Auto Book.* New York: McGraw-Hill, Inc., 1974, pp. 335-38.

Crouse, William H. *Automotive Mechanics.* 7th ed. New York: McGraw-Hill, Inc., 1975, pp. 416-18.

Ellinger, Herbert E. *Automechanics.* 2nd ed. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1977, pp. 251-52.

Stockel, Martin W. *Auto Service and Repair.* South Holland, Illinois: The Goodheart-Willcox Co., Inc., 1975, pp. (23-3) - (23-4).

Toboldt, William K. and Johnson, Larry. *Automotive Encyclopedia.* South Holland, Illinois: The Goodheart-Willcox Co., Inc., 1975, pp. 218-19.

Special-Purpose References

Johnson, James A. *Automotive Diagnosis and Tune-Up.* New York: McGraw-Hill, Inc., 1972, pp. 239-40.

Wetzel, Guy F. *Automotive Diagnosis and Tune-Up.* 6th ed. Bloomington, Illinois: McKnight Publishing Co., 1974, pp. 88-89, 97.

Personal and Service Safety Practices

Safety When Working around Spark Plugs

Vehicle finish. Always use fender covers when working under the hood. This will keep the fenders from getting scratched.

Procedures. Follow correct procedures and use correct tools when disconnecting the spark plug wires to prevent stretching and possibly breaking spark plug wires. Follow correct procedures and use correct tools when removing and installing spark plugs to prevent breaking insulators or tightening spark plugs incorrectly.

Care of eyes. Always wear eye protection equipment when using compressed air to blow dirt away from around the spark plugs. This will prevent dirt and other debris from getting into your eyes.

Safety Requirements When Working with Hydraulic Equipment

You may find it easier to remove and install spark plugs on some engines from under the vehicle. If you can easily get to the plugs without lifting the vehicle, the following safety practices do not apply.

Hydraulic floor jacks and jack stands

- Place the jack securely under the vehicle frame.
- Slowly raise the vehicle with the jack.
- Always support the vehicle with a jack stand in a secure position under the vehicle.
- Store the jack handle. Do not leave it on the floor where someone could trip over it.

Hydraulic lift equipment.

- Never put more weight on the lift than its rated capacity. (You'll find the lift's rated capacity on the lift.)
- Never rock the vehicle while it is on the lift.

- Always be sure the vehicle is securely on the lift before you raise the lift.

Safety When Making Cylinder Compression Tests

- Always follow the compression tester manufacturer's instructions. This will prevent damage to the equipment and incorrect test readings.

Safety in Work Clothing and Grooming

Hair. Keep hair away from moving parts. Keep hair under a hat if hair is longer than conventional length (over your shirt collar).

Jewelry. Avoid wearing any metal (rings, buckles, wristwatches, necklaces, etc.) that can come in contact with electricity. You can receive a severe burn if the metal you are wearing touches the electrical unit. You could also damage the electrical unit.

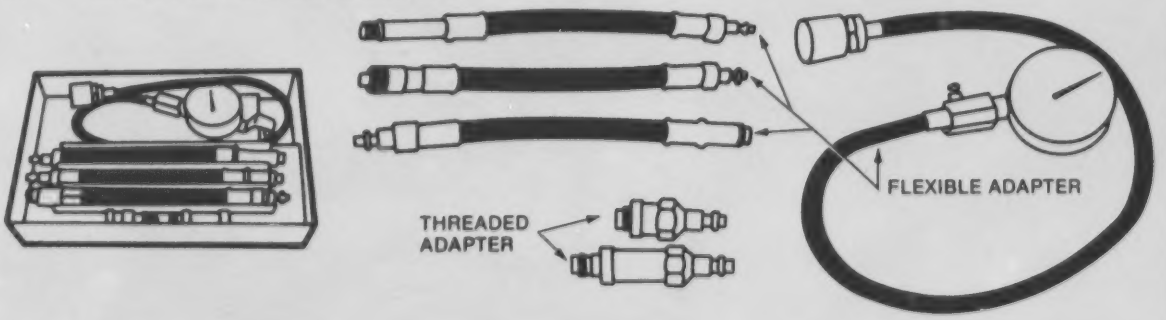
Clothing. Avoid wearing loose clothing, which can hang down and get caught up in the moving parts of an operating engine.

Procedures for Doing a Cylinder Compression Test

Purpose of the Test

In this section, you'll read about how to use a compression tester to check for bad engine conditions. The compression test, like the cylinder leakage test, is done after a cylinder power balance test in which one or more cylinders show an excessive drop in RPM or show a reading that varies quite a bit from the other cylinders. At that point you know that, on the cylinders that vary, the fault is mechanical. The cylinder compression test helps you pinpoint the troublesome part.

Figure 21-1 Compression Tester and Its Components



The compression tester locates compression losses in an engine. The tester serves the same purpose as the cylinder leakage tester; it is used when a cylinder leakage tester is not available. Compression testers are designed for hard-to-reach spark plug holes. They have offset adapters, flexible adapters, extensions, and threaded adapters that screw into the spark plug openings. The gauge shows the amount of pressure in pounds per square inch (psi).

Compression losses can happen at the intake and exhaust valves, the piston rings, or the head gasket. The compression tester tells you which parts are at fault.

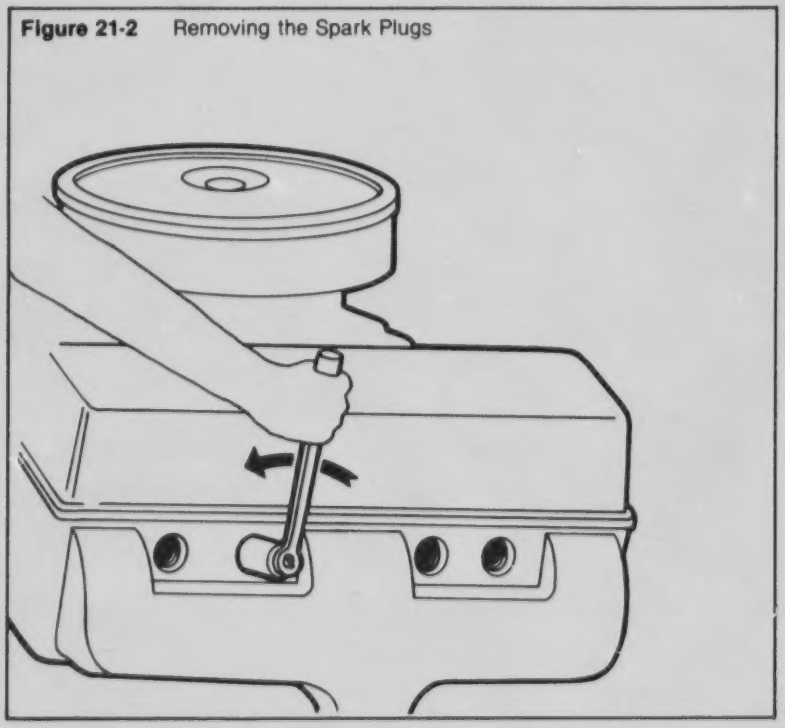
Briefly, you use the tester like this:

- With the engine at operating temperatures and all the spark plugs removed, place the tester into a spark plug hole.
- Crank the engine about four or five compression strokes while you watch the gauge readings.
- Write down the highest readings of each cylinder, and look for the cylinders that show the greatest variations from the others.

Step-By-Step Procedures

Be sure the engine is at normal operating temperatures before you do the compression test.

Figure 21-2 Removing the Spark Plugs



STEP 1 On a piece of paper, draw a chart like the one below. If you will be testing more than one engine, draw a chart for *each* engine.

Figure 21-3 A Chart for Recording Cylinder Compression Readings

CYL. NO.	1	2	3	4	5	6	7	8
COMPRESSION READING								

STEP 2 Remove all the spark plugs from the cylinders (see figure 21-2). Be sure you follow the proper procedures for removing spark plugs.

STEP 3 Remove the carburetor air cleaner. Block the throttle valve in the wide-open position, and be sure the choke is fully open.

STEP 4 Ground the coil high-tension lead. This will keep the secondary wires from sparking at each cylinder.

STEP 5 Connect the remote starter switch to the solenoid or starter relay.

STEP 6 Insert the compression gauge *tightly* into the spark plug hole (see figure 21-4). You can start with the #1 cylinder or with the cylinder that had the lowest reading during the cylinder power balance test.

With engines that have hard-to-reach spark plug holes, use one of the adapters (offset, flexible hose, threaded type) so that the gauge can be placed into the spark plug hole correctly.

STEP 7 Crank the engine for four or five compression strokes to obtain the highest possible reading (see figure 21-5).

STEP 8 On the chart you drew in Step 1, record the compression tester reading for the cylinder being tested.

STEP 9 Using Steps 6, 7, and 8, check the compression for each of the other cylinders, and record the highest compression reading for each one.

Figure 21-4 Inserting a Compression Gauge into Spark Plug Hole

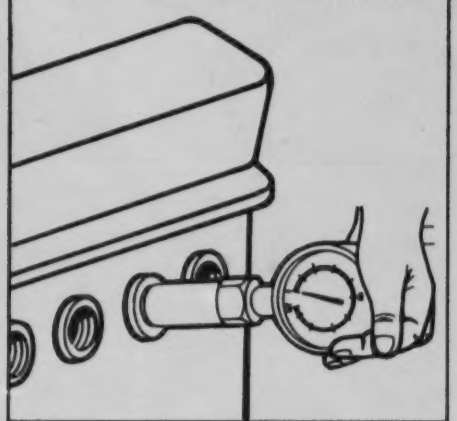
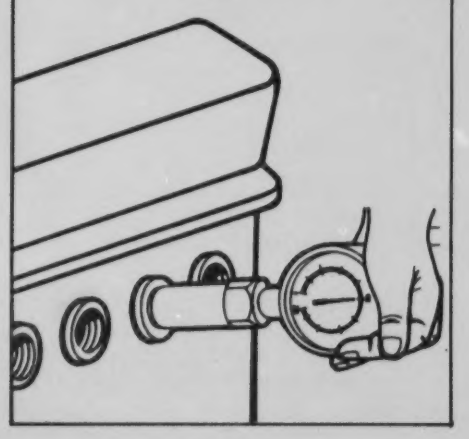


Figure 21-5 Reading the Compression Gauge



Compression Test Results

Refer to your technical service manual and the vehicle manufacturer's specifications for acceptable compression pressures. Some manufacturers do not present high or low compression standards, but instead give compression variation limits. For example, one manufacturer specifies that compression should not vary more than 20 psi between cylinders, while another specifies a no more than 10 psi variation between cylinders.

Normal compression pressure readings. You can use a compression pressure table to determine whether pressures are normal. Table 21-1 shows a typical compression pressure table. Compression pressures are considered to be normal if the lowest reading cylinder has more than 75 percent of the pressure of the highest reading cylinder.

Table 21-1 Compression Pressure

High Pressure (PSI)	Low Pressure	High Pressure (PSI)	Low Pressure
134	101	186	140
136	102	188	141
138	104	190	142
140	105	192	144
142	107	194	145
144	108	196	147
146	110	198	148
148	111	200	150
150	113	202	151
152	114	204	153
154	115	206	154
156	117	208	156
158	118	210	157
160	120	212	158
162	121	214	160
164	123	216	162
166	124	218	163
168	126	220	165
170	127	222	166
172	129	224	168
174	131	226	169
176	132	228	171
178	133	230	172
180	135	232	174
182	136	234	175
184	138	236	177

From *National Service Data Tune-Up (1), Tune-up, Carburetion, and Trouble Shooting.* ©1975 Mitchell Manuals, Inc. Used with permission of Mitchell Manuals, Inc.

To use the table, locate, in the *High Pressure* column, the highest pressure reading obtained on the compression test. The pressure shown opposite it, in the *Low Pressure* column, is the lowest pressure that can be considered normal for the engine. For example, if the high reading on the engine is 200 psi, the other cylinders should not give readings of less than 150 psi. Notice that 150 psi

(the lowest reading) is 75 percent of 200 psi (the highest reading).

Therefore, engine compression pressure readings are:

GOOD When compression test readings do not vary more than 10-20 psi between cylinders, as specified by the vehicle manufacturer.

When, if no specifications are available, the lowest cylinder reading is more than 75 percent of the highest cylinder reading.

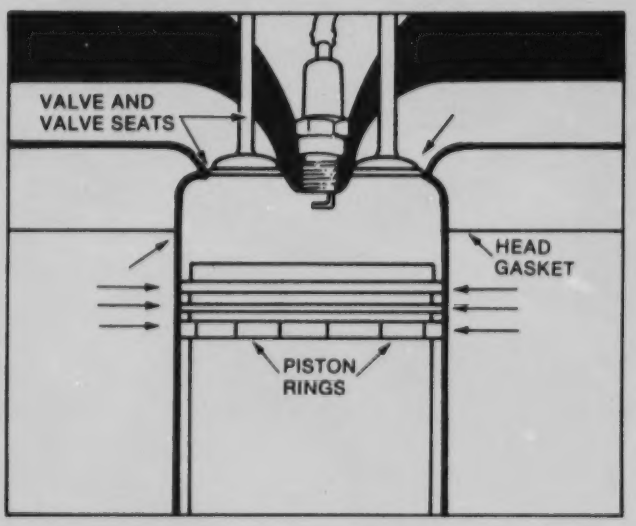
BAD When the compression test results give a low reading for one or more cylinders, with reading variations greater than those specified in the *GOOD* classification above.

Remember: Variations between cylinders will have more effect upon engine performance than will readings that are even but slightly below specifications.

Low compression pressure readings. Squirt about a tablespoon of engine oil (30W) through the spark plug hole into each cylinder that has a low-compression reading. Then:

- Crank the engine several strokes to spread the oil on the cylinder walls and rings.
- Recheck the compression readings on the low-compression cylinders.

Figure 21-6 Possible Cylinder Leakage Areas



Results.

- If compression increases, the trouble is caused by worn rings, (see figure 21-6).
- If compression does not increase, the trouble is caused by bad valves.
- If compression does not increase on two side-by-side cylinders that have equally low pressures, the head gasket is probably the faulty part. However, it could also be a cracked block or a warped cylinder head.
- Overall compression readings that are higher than normal indicate that too much carbon has built up in all cylinders. You should suspect this particularly if the engine has a ***pinging*** (spark knock) problem or is ***dieseling*** (the engine continues to run after the ignition is turned off).

Completing the Cylinder Compression Tests

- Check the spark plugs. You should always clean, file and, if needed, regap the spark plugs when they have been removed from the engine.
- Reinstall the spark plugs. Be sure to tighten these to the proper torque specifications.
- Unblock the carburetor throttle valve and reinstall the air cleaner.
- Remove the remote starter switch.

Turn to your Review Exercise Book and complete Exercise 16.

WORK ACTIVITIES

Before doing a work activity, make sure you've learned all the information that comes before it in the Student Guide. If you need a review, read the information on the pages listed in parentheses next to each work activity. Do not begin any of the work activities until you have your instructor's approval. If you're not sure that you can do a work activity, ask your instructor for help.

1. Do a compresion test on a V-8 engine suspected of having faulty cylinders (pages 139-147). Write down the compression test reading cylinder.

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

2. Analyze the test results. Diagnose the defective parts in the faulty cylinder(s) (pages 145-147).

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

When you have finished these activities, ask your instructor to return your pretest on Performance Objective 21. Complete the questions that you missed or were unable to answer the first time you took the pretest. Check your answers with your instructor when you finish. Your instructor will tell you if you are ready to be checked off on the performance checklist, or if you need to correct some of your answers first.

If you are told by your instructor that you are ready for the performance checklist, carefully tear the checklist out of your Review Exercise Book and give it to your instructor.

PERFORMANCE OBJECTIVE 22

TEST AND REPAIR TRANSISTOR IGNITION SYSTEM

145

INTRODUCTION

In this performance objective, you'll read about testing and repairing transistor ignition systems.

Transistor distributors are very similar to conventional distributors. For this reason, you may find it helpful to review Performance Objectives 10, 11, and 12 in Unit 3. Those three performance objectives include information about removing and installing distributors, strobing distributors and adjusting advance mechanisms, and overhauling distributors.

After you have finished all the activities for Performance Objective 22, your instructor will use a checklist like the one that follows to evaluate your work.

Performance Checklist—P.O. 22

Your instructor will provide either a live vehicle or live engine equipped with a transistor ignition system for this objective. Test the transistor ignition system, and repair any malfunctions you find. All of the performances below must be accomplished.

Student Performances

1. Visually inspects all wiring and connections.
2. Checks battery capacity, and records results.
3. Checks scope patterns and spark plug firing voltages, using an engine analyzer; records results.
4. Checks available voltage output, and records results.
5. Follows manufacturer's detailed component testing procedures, and records results.
6. Repairs or replaces defective parts as necessary.
7. Uses proper tools and equipment.
8. Follows all appropriate safety precautions.
9. Does performance in an acceptable amount of time.

Instructor Ratings

Acceptable	Not Acceptable	Omit

SAMPLE

Tools and Equipment

You will need to use the following tools and equipment when you do work activities for Performance Objective 22. You should already be able to use a basic hand tool set; so no procedures are provided here. The procedures for using special tools and equipment will be provided as you work through the activities in the Student Guide.

Basic Hand Tools

Basic Equipment

fender cover
extension light
ohmmeter
voltmeter

Special Equipment

engine performance tester
distributor tester
electronic ignition tester

Reading List

The Student Guide has been carefully designed to provide you with only the information you need to know to complete each performance objective. If you would like additional information, however, you may wish to use the references below.

General References

Crouse, William H. ***The Auto Book.*** New York: McGraw-Hill, Inc., 1974, pp. 274-79.

Crouse, William H. ***Automotive Mechanics.*** 7th ed. New York: McGraw-Hill, Inc., 1975, pp. 299-301, 315.

Ellinger, Herbert E. ***Automechanics.*** 2nd ed. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1977, pp. 211-12.

Stockel, Martin W. ***Auto Mechanics Fundamentals.*** South Holland, Illinois: The Goodheart-Willcox Co., Inc., 1974, pp. 67-71.

Stockel, Martin W. ***Auto Service and Repair.*** South Holland, Illinois: The Goodheart-Willcox Co., Inc., 1975, pp. (21-31)-(21-33).

Toboldt, William K. and Johnson, Larry. ***Automotive Encyclopedia.*** South Holland, Illinois: The Goodheart-Willcox Co., Inc., 1975, pp. 418-23.

Special-Purpose References

Crouse, William H. *Automotive Electrical Equipment.* 8th ed. New York: McGraw-Hill, Inc., 1976, pp. 190-95, 227-30.

Johnson, James A. *Automotive Diagnosis and Tune-Up.* New York: McGraw-Hill, Inc., 1972, pp. 441-56.

Wetzel, Guy F. *Automotive Diagnosis and Tune-Up.* 6th ed. Bloomington, Illinois: McKnight Publishing Co., 1974, pp. 150-51, 328-33.

Personal and Service Safety Practices

Safety When Making an Electrical Test

Procedures. Follow procedures described by electrical test equipment manufacturer's procedures. This includes proper care and use of the equipment, as well as correct calibration of the equipment when you first start to use it.

Electrical tests. Never do any electrical tests when you are standing on a wet surface or when the vehicle or engine parts are wet. A painful shock may result.

Safety When Making Ignition Tests with an Oscilloscope

- Always keep the scope leads away from the fan belts and the engine fan blades. Damaged scope leads are expensive to replace.

Safety When Working around an Operating Engine

Vehicle finish. Always use fender covers when you work under the hood. This prevents scratching the finish of the fenders with tools and equipment.

Personal safety. Avoid reaching into the engine without first looking. Your fingers could get caught in the moving parts when the engine is cranking or operating.

Procedures. Follow correct procedures when disconnecting spark plug wires to prevent stretching and breaking the spark plug wires unnecessarily.

Safety When Working around the Distributor

- Always wipe the distributor cap clean, and clean the work area before removing the cap. This will prevent dirt from getting inside the distributor.
- Be careful when cleaning the timing marks. Do not crank the engine while your hands or a cloth are near the lower pulley and engine fan blades. Injury can result.
- Be careful when using the timing light near the engine fan blades to prevent damage to the timing light.

Safety in Work Clothing and Grooming

Jewelry. Avoid wearing any metal (rings, buckles, wristwatches, necklaces, etc.) that can come in contact with electricity. You can receive a severe burn and also cause damage to the electrical unit.

Clothing. Avoid wearing loose clothing, which can hang down and get caught in the moving parts of an operating engine. Injury can result. Loose clothing can also catch on engine parts and tear.

Hair. Keep hair away from the moving parts of an operating engine. Keep your hair under a hat if your hair is longer than conventional length (over your shirt collar).

Transistor Ignition Systems

Description

Electronics and solid state components in automotive ignition systems are being used throughout the industry. These new ignition systems are called transistor ignition systems or electronic ignition systems. Because these systems are more efficient than conventional ignition systems, the vehicle manufacturers have been able to meet many of the federal government's strict emissions regulations.

These new ignition systems, all-electronic in principle, are called different names by different vehicle manufacturers. For example, ***solid-state ignition system*** is the name Ford Motor Company gives its system. ***Electronic ignition system*** is the name used by Chrysler Corporation. ***High-energy ignition system*** (HEI) is the name General Motors Corporation gives its system. At the present time, all have one thing in common: they do not use contact points and condensers.

In this performance objective, you will learn how to test and repair these modern transistor or electronic ignition systems.

Principles of Operation

The three transistor ignition systems mentioned above operate on the same basic principles as conventional systems do.

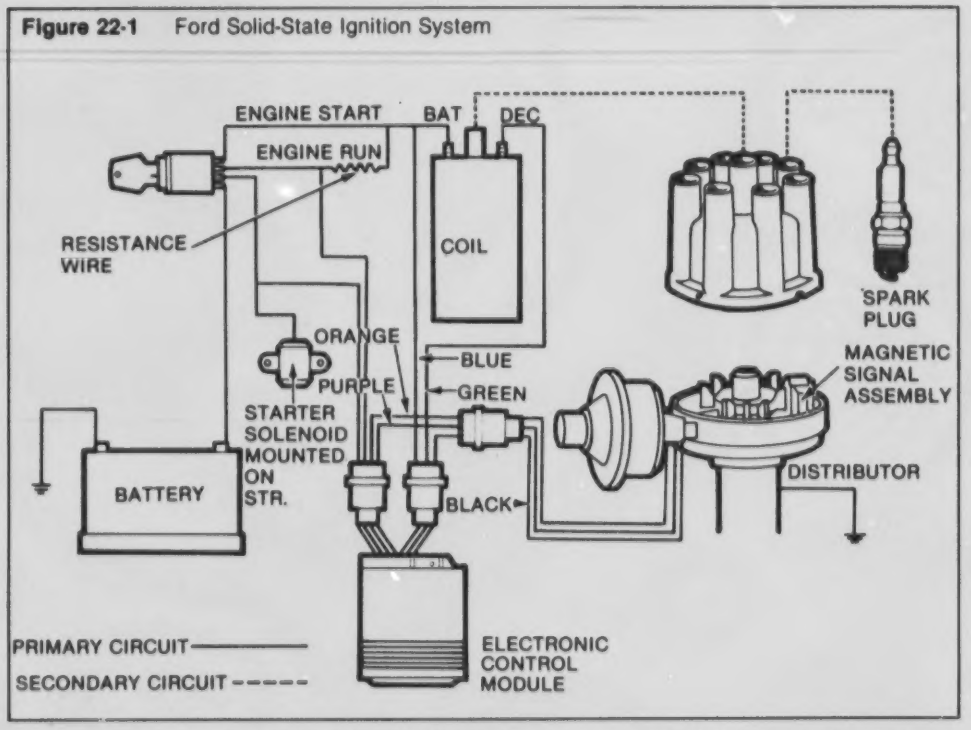
The distributor, which looks like any other distributor, has no contact points, distributor cam, or condenser. The distributor operation is controlled by a ***magnetic signal assembly*** that sends electrical pulses to an ***electronic control module.*** The electronic control module is sometimes referred to as a control unit, amplifier module, or ignition pulse amplifier. Whatever the name, the electronic

control module switches off the flow of current to the coil primary windings. This induces the secondary windings of the coil to build up a high voltage charge, which is then distributed to the spark plugs exactly as it is in the conventional system.

The other components of the electronic ignition system—coil rotor, distributor cap, mechanical advance mechanism, vacuum advance mechanism, secondary wires, and spark plugs—are the same as those of a conventional system, and they operate in the same way.

In figure 22-1, you can see that the control module and the coil are individual units—separate from the distributor. The one exception is the GM high-energy ignition system for V-8 and V-6 engines. The coil and the control module are installed in the distributor of the GM model; so the distributor is a single electronic assembly.

Figure 22-1 Ford Solid-State Ignition System



Adapted from *Sun 2001 Diagnostic Computer. Operator's Manual.* ©1976 Sun Electric Corporation. Used with permission of Sun Electric Corporation.

The magnetic signal assembly in the distributor varies in detail from one ignition system to another. Generally, however, they are all based on the same principle.

Figure 22-2 Magnetic Signal Assembly in a Distributor

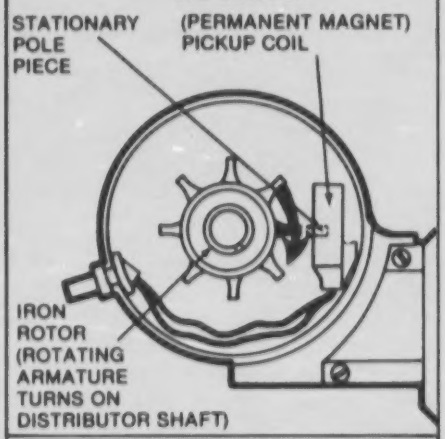


Figure 22-3 Electrical Signal Generated in the Pickup Coil

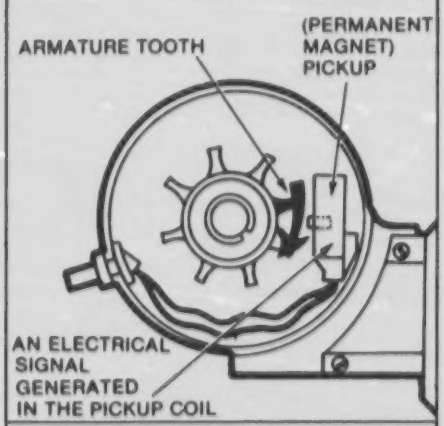
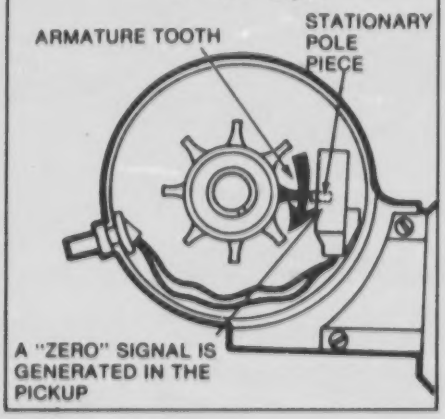


Figure 22-4 Tooth and Stationary Pole Piece Aligned to Generate a "Zero" Signal



A gear-shaped *iron rotor* driven by the distributor shaft rotates past the *stationary pole piece* of a *pickup coil* (see figure 22-2). The iron rotor is also called a reluctor, an armature, or a timer core. This is how it works:

- The number of teeth on the rotating armature is the same as the number of cylinders in the engine (see figure 22-3). As an armature tooth nears the magnet, an electrical signal is generated in the pickup coil.

  The signal goes to the control module, which then allows the voltage to build up in the coil primary windings (see figure 22-3).

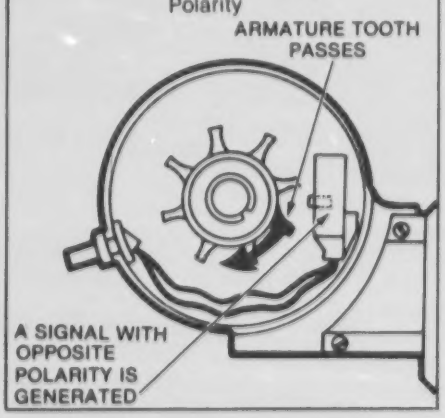
- At the point where the tooth and the stationary pole piece are exactly aligned with each other, a "zero" or "no signal" is generated in the pickup coil (see figure 22-4).

This breaks the primary circuit and stops the flow of current in the coil's primary winding. At this point, the coil discharges the high voltage in the secondary circuit to the spark plug, as in a conventional ignition system.

As the tooth of the armature moves away from the pole piece, a signal with opposite polarity is generated to the control module (see figure 21-5).

The timing circuit in the control module prepares the primary circuit for the next cylinder firing cycle to start. This preparation is called "making the primary circuit."

Figure 22-5 Armature Tooth Passes Pole Piece to Generate Signal with Opposite Polarity



Advantages of the Transistor Ignition System

There are two major advantages of the transistor ignition system.

- There is an almost total elimination of distributor servicing: there are no points to burn out or wear out in time; there is no rubbing block to wear down and thereby change point dwell periods and engine timing; and the power-switching action of the control module is not related to engine RPM and does not wear out with use.
- There is an improved spark plug service interval. The transistor ignition system provides higher secondary voltages. When this is combined with better "switching" action (no points), the spark plugs cannot misfire.

These advantages result in reduced vehicle emission, reduced need for ignition system maintenance (fewer tune-ups), and extended mileage with troublefree operation.

Comparison of Ignition System Components

The table below should help you recognize both the similarities and the differences between the transistor ignition system and the conventional systems.

Table 22-1 Ignition System Components

CONVENTIONAL SYSTEM	TRANSISTOR SYSTEM
distributor	same
contact points	armature or reluctor
rubbing block	pickup coil control module
distributor cam	----------
cam lubricant	----------
contact point dwell adjustment	----------
condenser	----------
rotor	same
distributor cap	same
mechanical advance mechanism	same
vacuum advance mechanism	same
spark plug wires	same
spark plugs	same
ignition coil	same
secondary ignition circuit	same
distributor timing adjustment	same

Oscilloscope Engine Hookup

Testing with a scope is the same for both electronic ignition systems and conventional systems. However, there are some minor differences in both engine hookups and scope pattern waveform appearances. First, you'll learn how to hook up the scope on an engine with an electronic ignition system.

(1) On the Chrysler electronic ignition systems and the Ford solid-state ignition systems, the scope hookup connections are the same as on a conventional ignition system.

The dwell test is not made on these ignition systems because they do not have contact points.

On the Ford solid-state system, the negative terminal of the ignition coil uses the marking ***DEC, distributor electronic control.***

Engine Test Connections

- Clamp the chrome pattern pickup around the secondary coil wire.
- Clamp the red trigger pickup around the #1 spark plug wire at a point near the distributor.
- Connect the red primary tester lead to the distributor or DEC (–) terminal of the coil.
- Connect the black primary ground tester lead to a good ground on the engine block.
- Connect the tester battery leads to the battery terminals. The red (positive) lead is connected to the POS (+) battery terminal.
- Connect the black (negative) lead to the NEG (–) battery terminal.

(2) For General Motors high-energy ignition systems, use the special adapters that come with the scope.

On General Motors L6 and 4-cylinder engines, an adapter lead (jumper) is used to connect the red primary tester lead to the system's "Tach" terminal on the coil (see figure 22-6). All other tester connections are made in the usual way.

Figure 22-6 Scope Hookups on General Motors L6 and 4-Cylinder Engines (Coil Separate from Distributor)

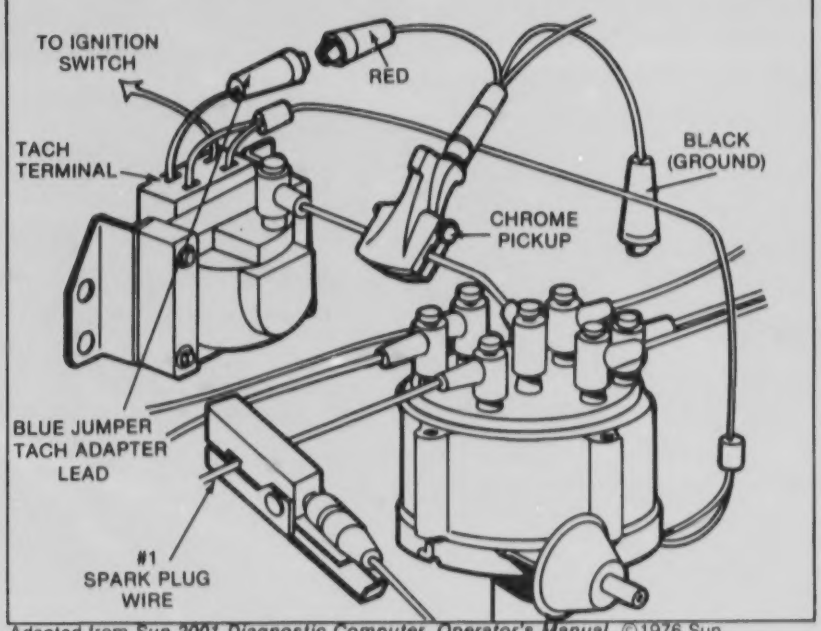


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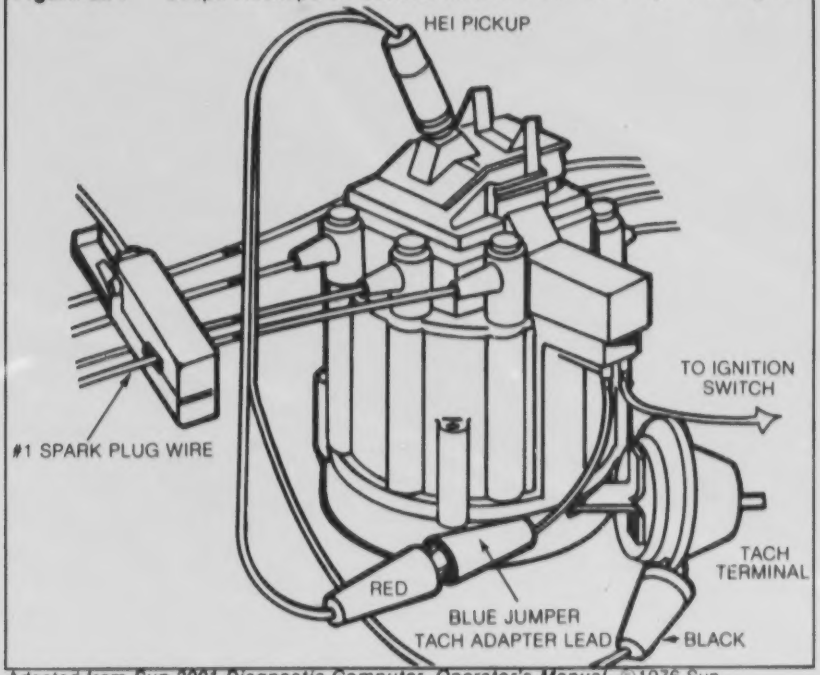
Figure 22-7 Scope Hookups on General Motors V-8 and V-6 Cylinder Engines



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However, on General Motors V-8 and V-6 engines, one additional adapter (the HEI pickup) is used, which takes the place of the chrome pattern pickup clamp (see figure 22-7). To attach the HEI pickup, first unscrew the chrome clamp and install the adapter. Then snap the pickup into place on top of the coil cover. Keep in mind that, on these distributors, the coil and the electronic module are one unit that is part of the distributor. The General Motors V-8 and V-6 engines also use the jumper lead adapter to connect the red primary tester lead to the systems "Tach" terminal on the coil (see figure 22-7).

Turn to your Review Exercise Book and complete Exercise 17.

WORK ACTIVITIES

Before doing a work activity, make sure you've learned all the information that comes before it in the Student Guide. If you need a review, read the information on the pages listed in parentheses next to the work activities. Do not begin any of the work activities until you have your instructor's approval. If you're not sure you can do a work activity, ask your instructor for help.

1. Look at several vehicle transistor ignition systems and identify the parts and wiring that make up each system (pages 154-159).

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

2. Connect the scope test leads to a vehicle with a transistor ignition system (preferably GM's HEI V-8 and V-6 engines) (pages 158-160).

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

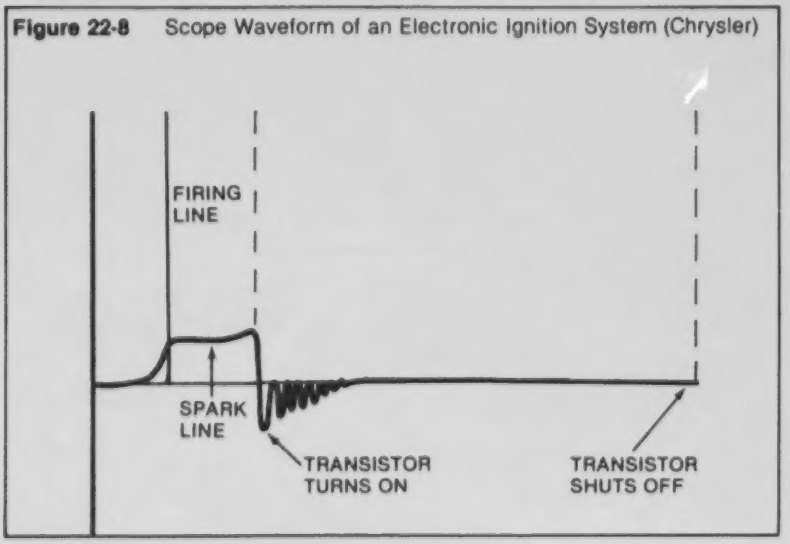
After you have finished these activities, go on to the next section.

Scope Patterns and Tests

Scope Patterns

This section is about transistor ignition system scope patterns. These patterns differ in appearance from one transistor ignition system to the next, depending on whether you are testing an electronic (Chrysler), solid-state (Ford), or high-energy (GM) system.

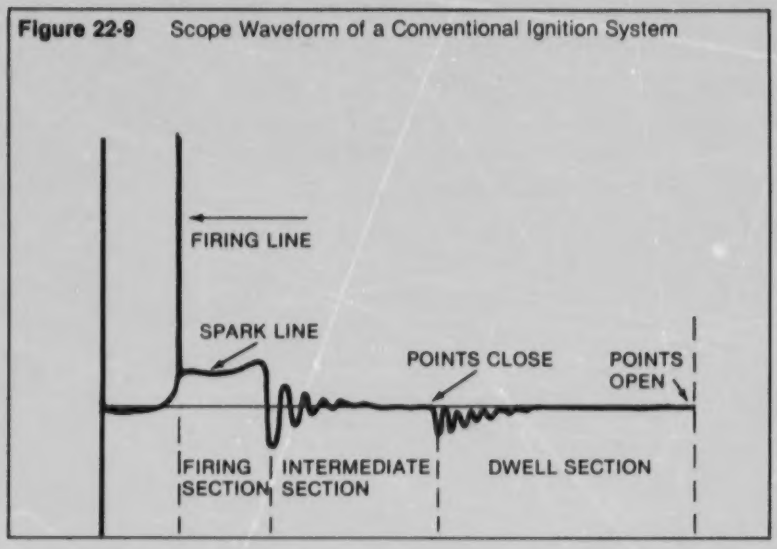
Figure 22-8 Scope Waveform of an Electronic Ignition System (Chrysler)



Chrysler electronic ignition system

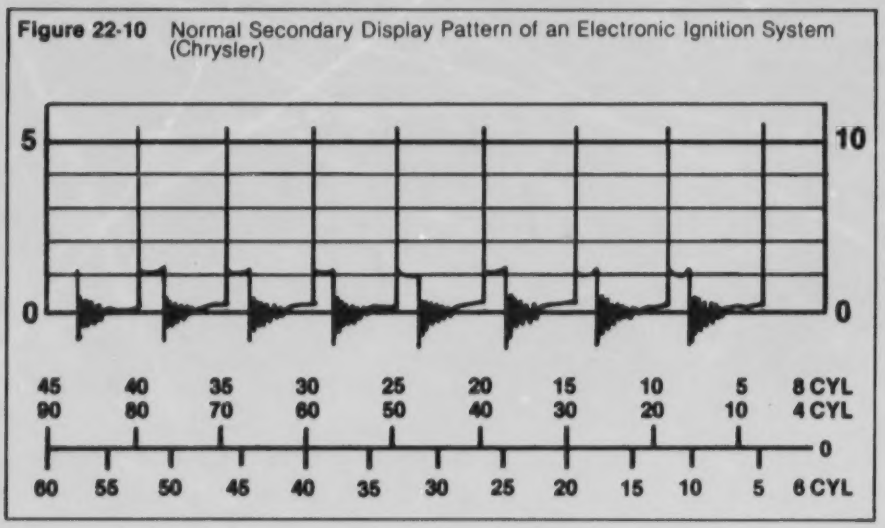
You can measure voltages and study waveform patterns of a transistor system just as you do those of a conventional system. In fact, the transistor's waveform is much simpler because there is no intermediate section or dwell section (see figures 22-8 and 22-9).

Figure 22-9 Scope Waveform of a Conventional Ignition System



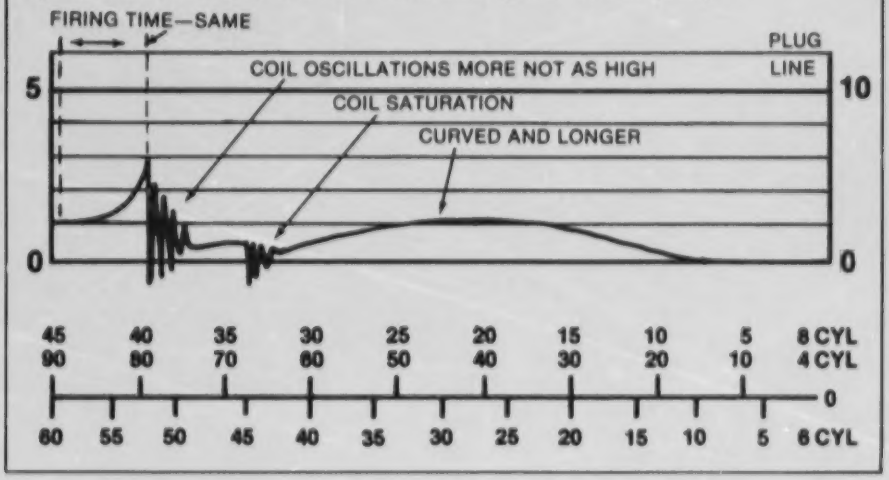
Notice that the firing lines and spark lines of the two types of systems are identical. For this reason, the information gained from the firing section of the pattern should be the same. The firing section includes the system's secondary circuit: spark plugs, spark plug wires, rotor, distributor cap, and any engine conditions analyzed in this section of the pattern.

Figure 22-10 Normal Secondary Display Pattern of an Electronic Ignition System (Chrysler)



In the example of a normal secondary display pattern shown in figure 22-10, the firing line is between 5 kv and 7 kv. The spark line is almost flat at about 1 kv. The oscillations following the firing section are clear and become smaller as the waveform traces back to the base line, zero.

Figure 22-11 The Waveform of the Solid-State Ignition System (Ford)


FIRING TIME—SAME
PLUG LINE
COIL OSCILLATIONS MORE NOT AS HIGH
COIL SATURATION
CURVED AND LONGER
5
10
0
0
45 40 35 30 25 20 15 10 5 8 CYL
90 80 70 60 50 40 30 20 10 4 CYL
0
60 55 50 45 40 35 30 25 20 15 10 5 6 CYL

On the solid-state system, shown in figure 22-11, the firing line is 7.5 kv and the firing time is the same as that of a conventional system. The coil oscillations are somewhat smaller, while the dwell line is longer and more curved than that of the Chrysler system.

Notice how the firing lines are spaced farther apart on the display pattern in figure 22-12. Figure 22-13 shows the normal raster pattern of Ford's solid-state ignition system.

Figure 22-12 Normal Secondary Display Pattern of a Solid-State Ignition System (Ford)

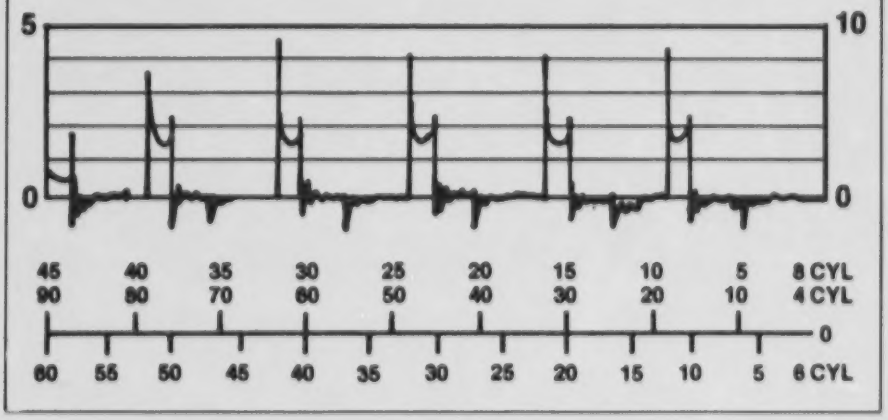
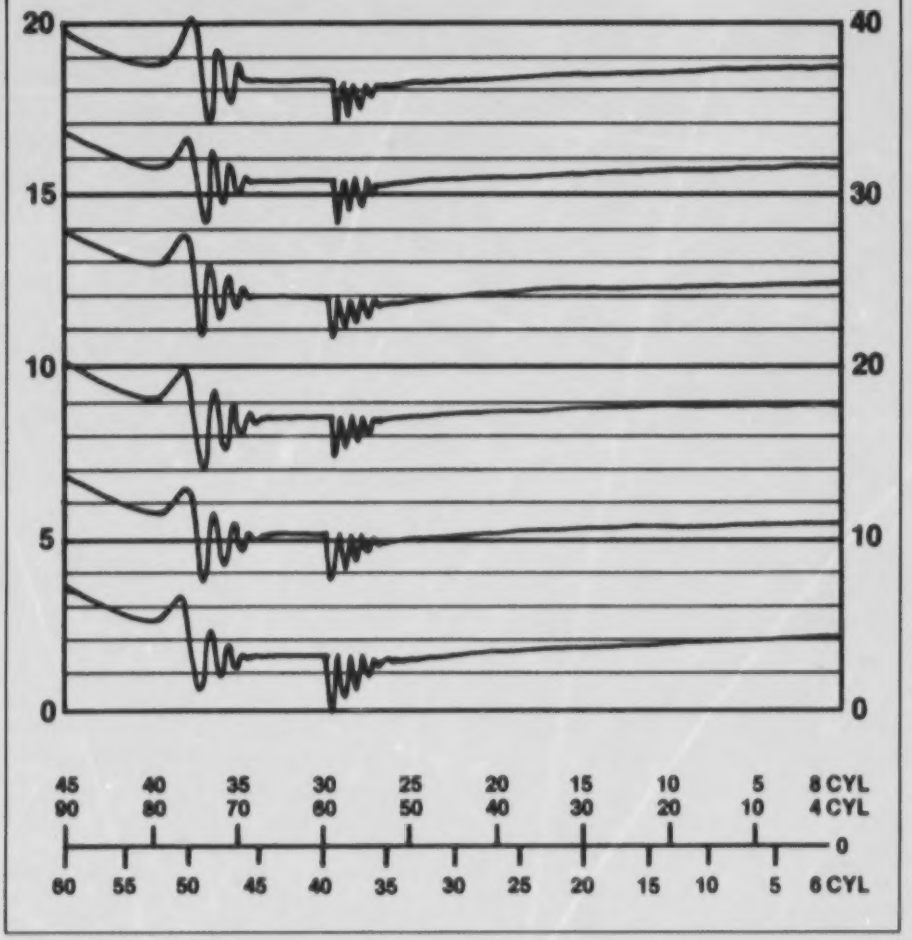


Figure 22-13 Normal Raster Pattern of a Solid-State Ignition System (Ford, 6-Cylinder Engine)



General Motors high-energy ignition system. The high-energy ignition system has two important variations. One is the unusual lump that appears in the dwell section. The other is the dwell period that will vary with a change in engine speed.

Figure 22-14 Normal Secondary Display Pattern of a High-Energy Ignition System (GM, V-8, 40 kv, Idle Speed)

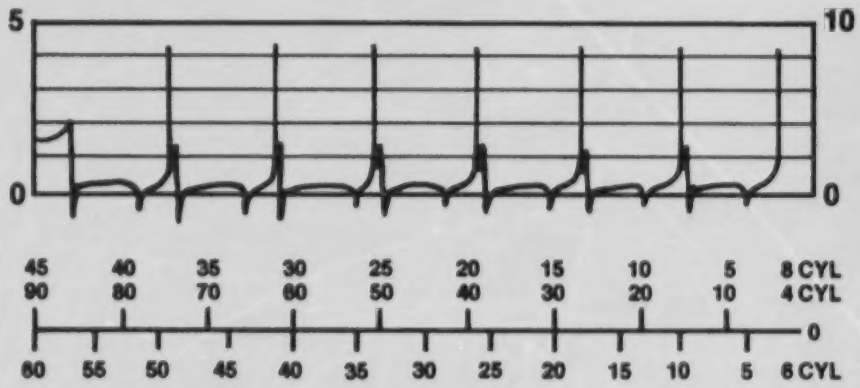
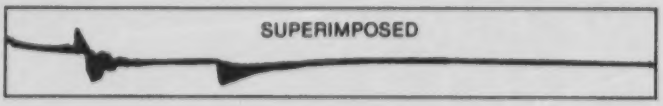
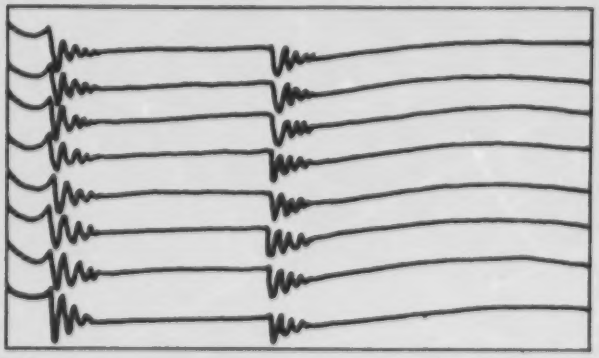


Figure 22-15 Normal Superimposed Pattern of a High-Energy Ignition System (GM, V-8)



Notice the difference in the appearance of pattern waveforms between the General Motors V-8 engine (see figures 22-16 and 22-17) and the V-6 engine (see figures 22-18 and 22-19). Both use the high-energy ignition system, although the coil in the V-6 engine is separate from the distributor.

Figure 22-16 Normal Secondary Raster Pattern of a High-Energy Ignition System (GM, V-8, Idle Speed)



160

Figure 22-17 Normal Secondary Raster Pattern of High-Energy Ignition System (GM, V-8, Cruise Speed). As Engine Speed Increases, the Dwell Period Lengthens

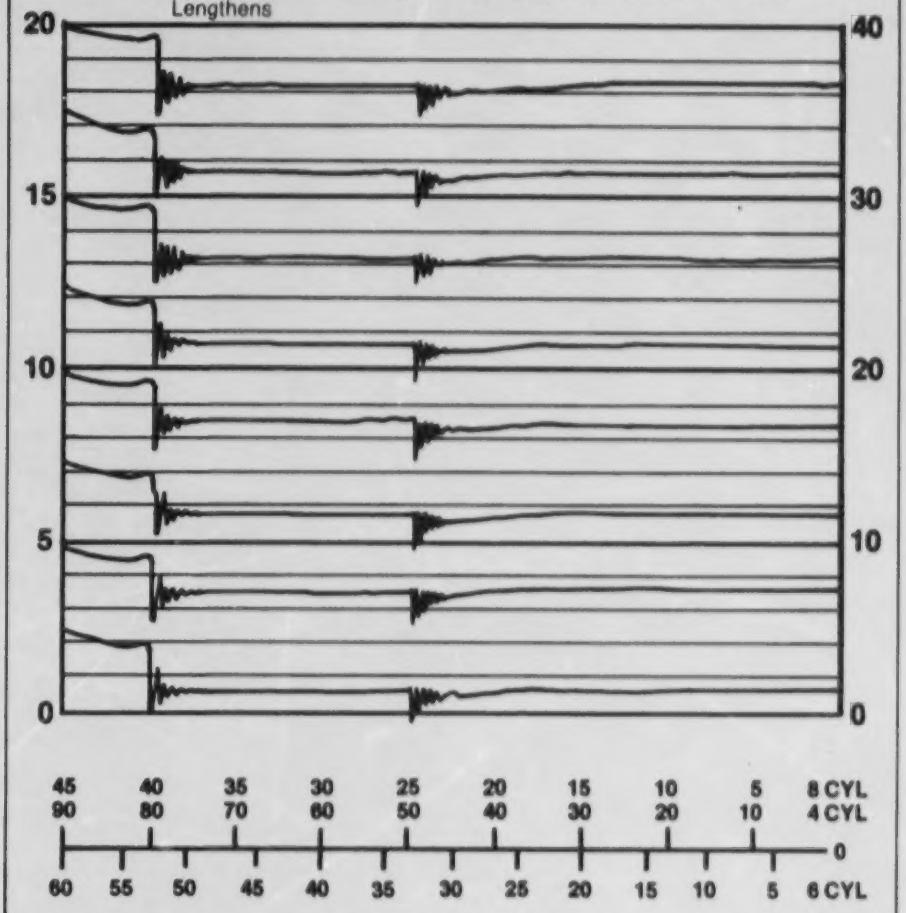


Figure 22-18 Normal Secondary Display Pattern of a High-Energy Ignition System (GM, V-6, 40 kv, Idle Speed)

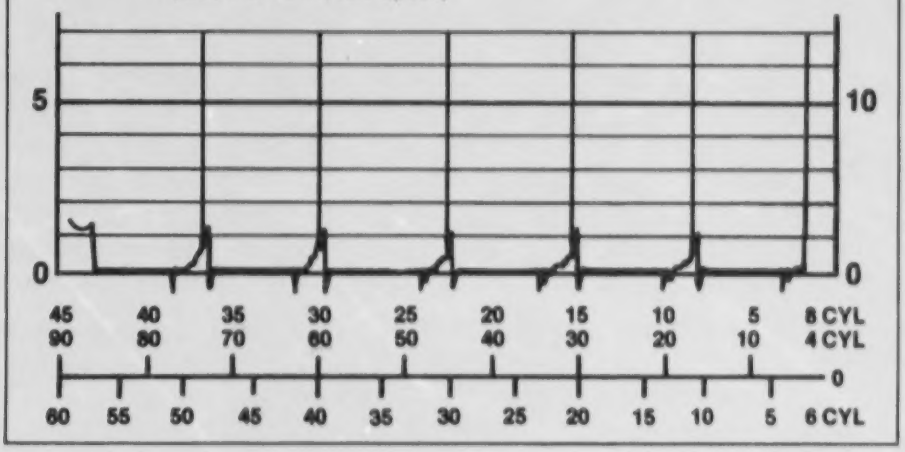
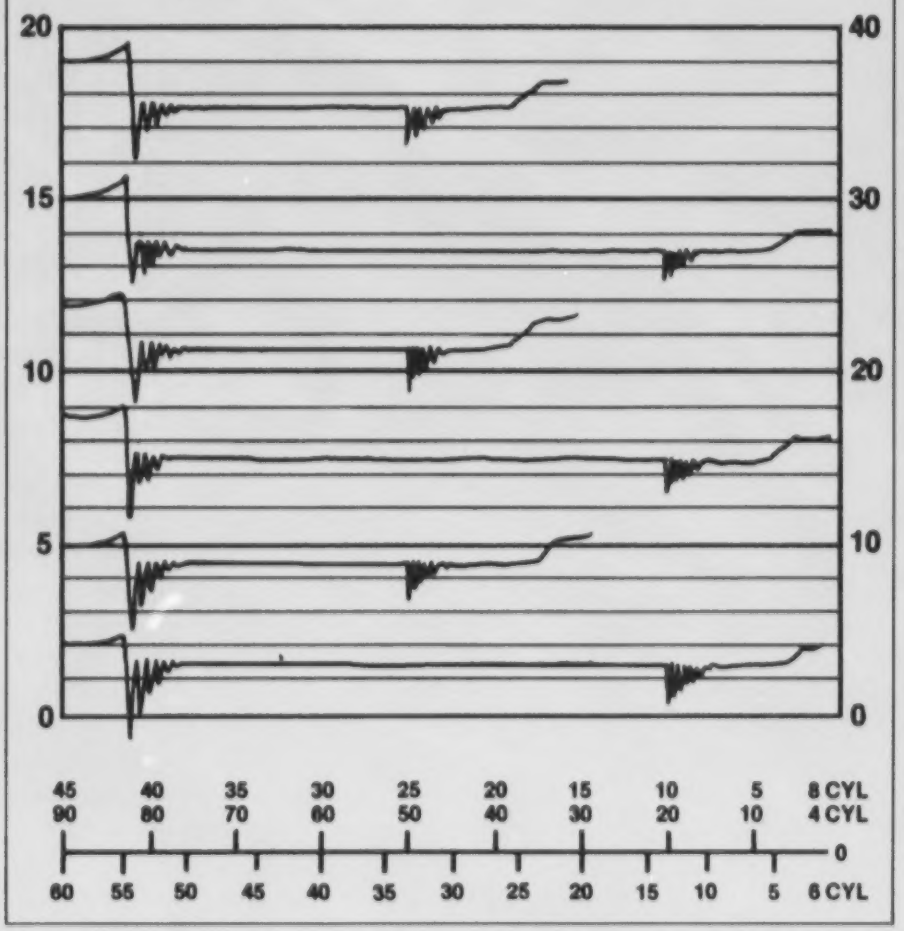


Figure 22-19 Normal Secondary Raster Pattern of a High-Energy Ignition System (GM, V-6, 40 kv, Idle Speed)



Scope Tests

There are three conditions that indicate a possible malfunction in the transistor ignition system:

- engine surges severely
- engine misses
- engine will not start

In this part of the performance objective, you'll read about ways to test for these three conditions by using a scope to analyze the transistor ignition system. The tests that you will be making apply to all three transistor ignition systems—Chrysler, Ford, and General Motors.

Later in this performance objective, you'll read about ways to do more detailed tests on the components of the three transistor systems—Chrysler, Ford, and GM. These

tests require the use of a voltmeter and an ohmmeter. Before you get to the component tests, do the three general tests discussed below.

Available voltage test. To analyze the first two engine conditions—***engine surging and missing***—you first do an available voltage test. This will tell you the general condition of both the primary and secondary ignition circuits.

To test for available voltage:

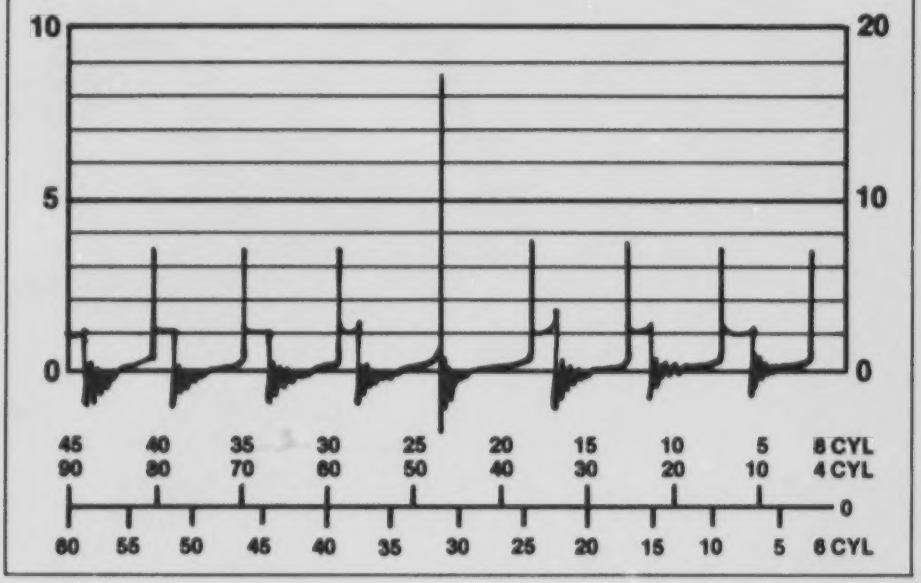
STEP 1 Adjust the scope to the secondary display pattern and the 40 kv scale.

STEP 2 With the engine operating at 1,500 RPM, remove one of the spark plug wires and hold it away from ground.

NOTE: On vehicles equipped with catalytic converters, a spark plug wire should be removed for no more than 30 seconds.

STEP 3 Look at the height of the spark plug firing line. The firing line should be 20 kv or more (see figure 22-20).

Figure 22-20 Normal Expected Pattern



STEP 4 Look at the downward part of the pattern. Its length should be equal to at least ***one half the upward height***, and it ***should be steady.*** (The downward part of the pattern shows the condition of the secondary insulation in the secondary circuit.)

STEP 5 Reinstall the spark plug wire.

STEP 6 Repeat the available voltage test on all the other spark plugs.

GOOD The available voltage test shows that the firing line is 20 kv or more. The downward part of the pattern is at least one-half the length of the upper part, which indicates that the secondary insulation is normal. If the test results show that the ignition system is operating normally, but the engine still surges and misses, check the fuel system and the mechanical condition of the engine.

BAD If the test results show that the ignition system does not meet the above standards, it will be necessary to do the detailed component tests. (These tests will be covered later in this performance objective.)

Spark plug firing voltages and engine condition tests. These scope tests are identical to those used on a conventional ignition system.

STEP 1 While the engine is operating at 1,500 RPM with the scope setting on the secondary display pattern and on the 40 kv scale, look at the firing lines.

- If you need to review the test indications for incorrect spark plug firing voltages, refer to Performance Objective 18. For engine condition indications, also refer to Performance Objective 18.

STEP 2 Turn the scope pattern selector to the raster position and check the length of the spark lines.

- Spark plugs with no gap or spark plugs that are completely fouled will have longer or extremely slanted spark lines.

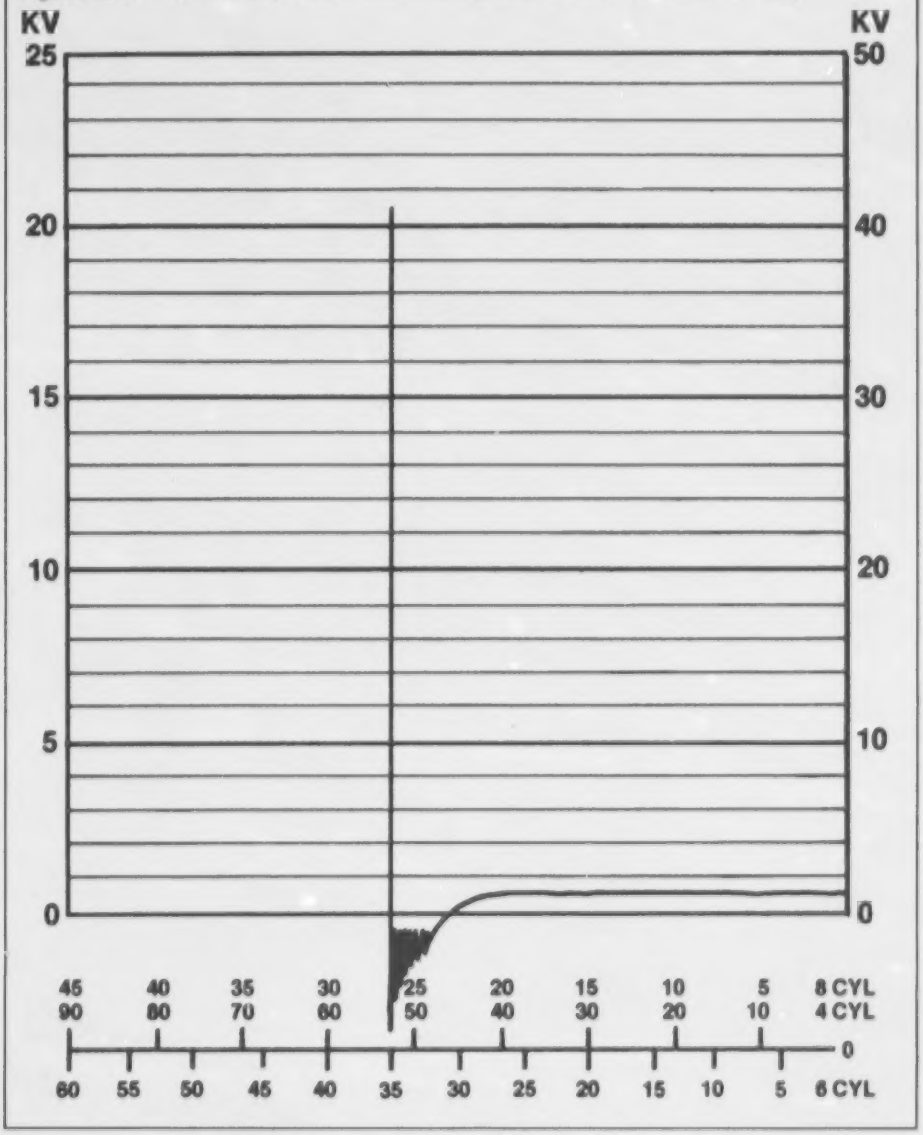
Cranking coil output test. If the engine will not start, do a cranking coil output test.

To test for cranking coil output:

STEP 1 Adjust the scope to the secondary display pattern and to the 40 kv scale.

STEP 2 Remove one of the spark plug wires and hold it away from ground while cranking the engine. Have an assistant crank the engine for you.

Figure 22-21 Normal Expected Pattern: Firing Line Is 20 kv (or 30 kv for HEI)



STEP 3 Look at the height of the spark plug firing line. The firing line should be 20 kv or more. (For General Motors HEI systems, the firing line height should be 30 kv or more.)

STEP 4 Reinstall the spark plug wire.

GOOD The height of the firing line is 20 kv or more (on HEI systems, 30 kv or more).

BAD If the firing line height is not 20 kv or more

(30 kv or more on HEI systems), it will be necessary to do the detailed component tests. (These tests will be covered later in this performance objective.)

Turn to your Review Exercise Book and complete Exercise 18.

WORK ACTIVITIES

Before doing a work activity, make sure you've learned all the information that comes before it in the Student Guide. If you need a review, read the information on the pages listed in parentheses next to each work activity. Do not begin any of the work activities unless you have your instructor's approval. If you're not sure you can do a work activity, ask your instructor for help.

3. Using a scope, analyze scope patterns and spark plug firing voltages for Chrysler, Ford, and General Motors transistor ignition systems. Check your testing results with your instructor after the testing of each transistor igniton system (pages 161-168).

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

4. Using a scope, do an available voltage test on each of the transistor ignition systems (Chrysler, Ford, GM) (pages 168-171).

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

After you have finished these activities, go on to the next section.

Detailed Component Tests

If the engine still malfunctions after you've done the scope tests and made necessary repairs, you will have to perform the detailed tests to locate the problem area.

Because each manufacturer's ignition system is different from every other manufacturer's system, these detailed tests are also done differently on the various systems.

Remember, on transistor ignition systems, the magnetic signal assembly, the armature or reluctor, and the electronic control module do not normally change or wear out with use. Consequently, engine timing and dwell do not usually require periodic adjusting. Because dwell is not adjustable, regular ignition maintenance involves:

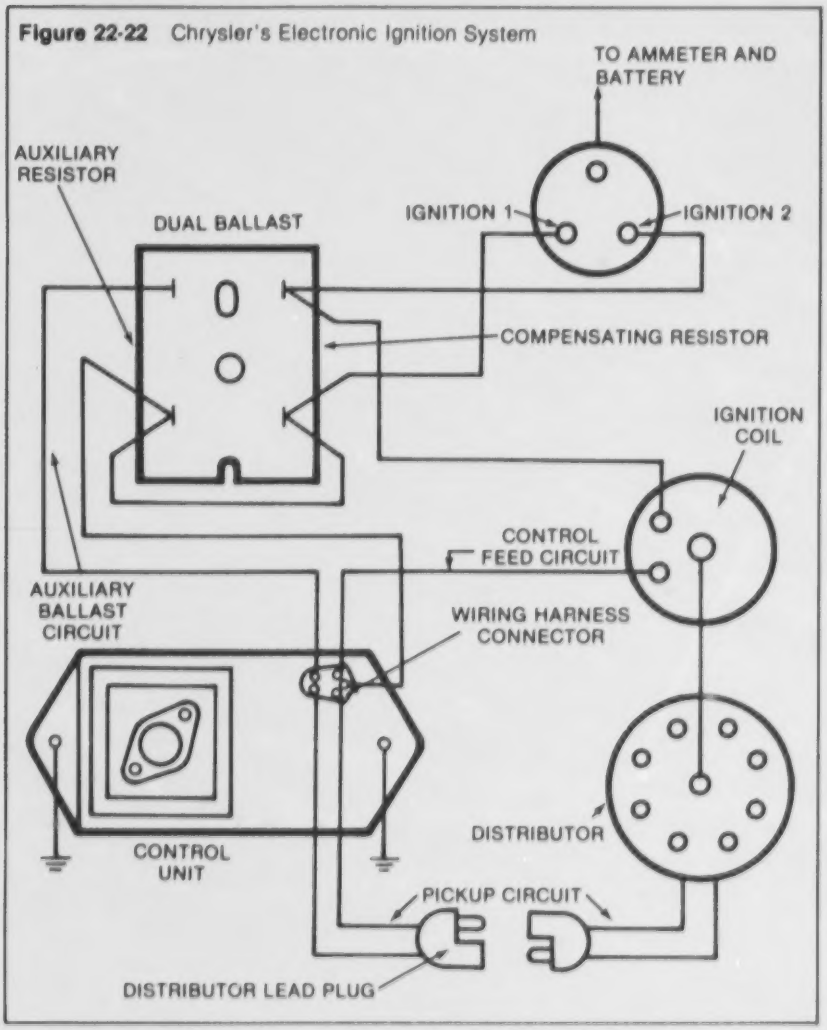
- cleaning and replacing spark plugs
- inspecting the distributor cap and the rotor
- inspecting and testing the magnetic distributor and the ignition wiring

This section will explain the last item: how to test the distributor and ignition wiring for each vehicle manufacturer's transistor ignition system.

Chrysler Electronic Ignition System

The Chrysler system consists of a magnetic distributor, electronic control unit, wire harness, coil, and a special dual ballast resistor (see figure 22-22). The detailed component tests will involve all of these parts.

Figure 22-22 Chrysler's Electronic Ignition System



Adapted from *National Service Data Tune-Up (II). Electrical Wiring Diagrams. Accessories and Equipment.* ©1975 Mitchell Manuals, Inc. Used with permission of Mitchell Manuals, Inc.

In the diagram, you can see that, in addition to the regular primary circuit from the ignition switch to the coil (including the bypass system), there are three other circuits. They are the pickup circuit, the control unit feed circuit, and the auxiliary ballast circuit. You'll have to test each circuit.

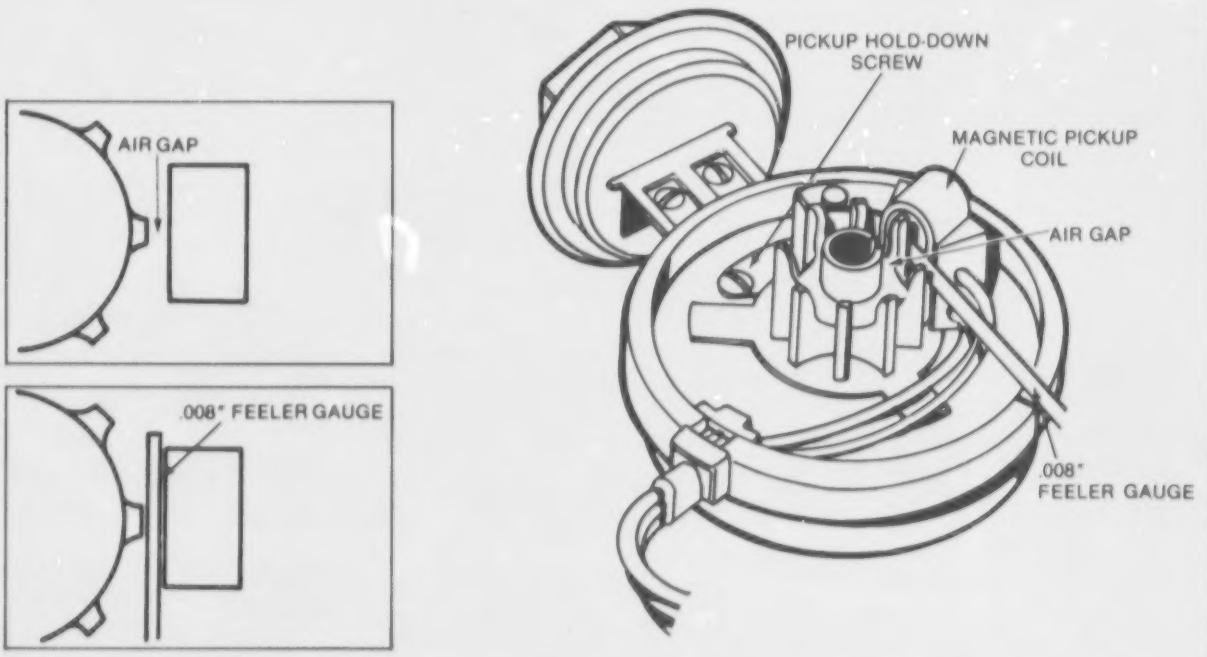
Wiring and connections checks

- First, inspect the secondary cables and the primary wires at the coil for looseness. Look for frayed or broken wires.
- Then, check the distributor lead plug for tightness and corrosion. Check the wiring harness connector at the control unit for the same conditions.
- Then, check the ballast resistor for looseness and cracks.
- Finally, check the control unit for tightness at its mounting. The control unit must have a good ground at its mounting.

Battery voltage test. Test the battery for acceptable voltages. Proper functioning of the ignition system depends on a battery that has a good charge. Write down the results, because you will refer to these test results later as you check out components.

Distributor tests. With the engine operating at the speed where surging occurs, disconnect the distributor vacuum advance line. If the surging stops, test the condition and adjustment of the magnetic pickup coil by following the procedure below.

Figure 22-23 Air Gap between the Reluctor and Stationary Pole Piece



Check and adjust the air gap between the reluctor or armature tooth and the stationary pole piece (see figure 22-23).

- Remove the distributor cap and rotor.
- Align one tooth of the reluctor directly across the pole piece.
- Insert an .008-inch feeler gauge between the reluctor tooth and the pole piece.

NOTE: The feeler gauge must be made of non-magnetic material. Otherwise, the gauge will become magnetized and it will be difficult to get an accurate measurement.

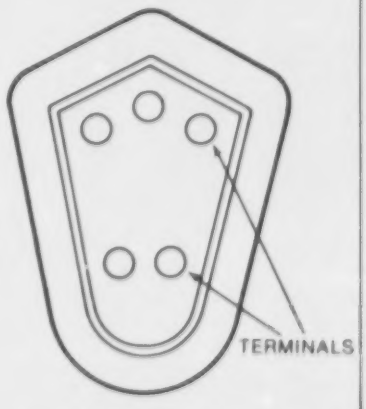
- To adjust, loosen the pickup hold-down screw. Move the pickup until contact is made between the pickup, the feeler gauge, and the reluctor tooth.
- Tighten the hold-down screw and remove the feeler gauge.

NOTE: No force should be needed when you remove the feeler gauge.

- Try to insert a .010-inch feeler gauge through the same gap. Remember, the air gap is correct if the feeler gauge fits without any use of force.
- Crank the engine and check to see if there is any interference between the reluctor and the magnetic pole piece. ***The reluctor teeth should not hit the pickup pole piece.*** Readjust the air gap if they do.

NOTE: If the teeth hit on only one side of the reluctor, the distributor shaft is bent.

Figure 22-24 Wiring Harness Connector

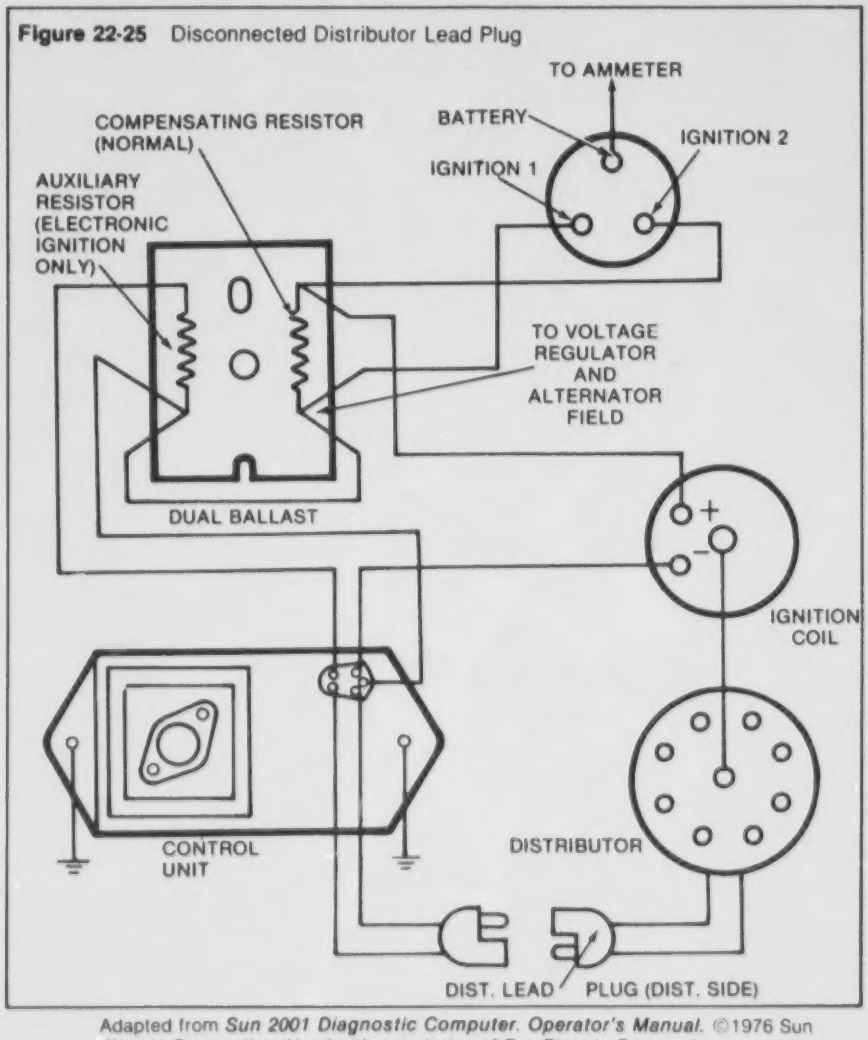


Distributor pickup coil tests

- Be sure the ignition switch is turned to off.
- Disconnect the wiring harness connector from the electronic control unit.
- Check the calibration of your ohmmeter. Connect the ohmmeter by attaching one tester lead to the #4 terminal of the wiring harness connector and the other tester lead to the #5 terminal (see figure 22-24).

NOTE: The ohmmeter resistance reading should be between 150 and 900 ohms. If the reading is not within these limits, disconnect the distributor lead plug coming from the distributor.

Figure 22-25 Disconnected Distributor Lead Plug



Adapted from *Sun 2001 Diagnostic Computer. Operator's Manual.* ©1976 Sun Electric Corporation. Used with permission of Sun Electric Corporation.

- Check the ohms resistance at the lead plug (distributor side) (see figure 22-25). To do this, connect one ohmmeter lead to one terminal of the lead plug and the other ohmmeter lead to the other terminal of the plug.

NOTE: If the reading is *not* between 150 and 900 ohms, replace the pickup coil assembly in the distributor. If the reading is within these limits, check the wiring harness between the control unit and the distributor lead plug.

- Connect one ohmmeter lead to a good ground. Connect the other lead to either of the terminals on the distributor lead plug (distributor side).

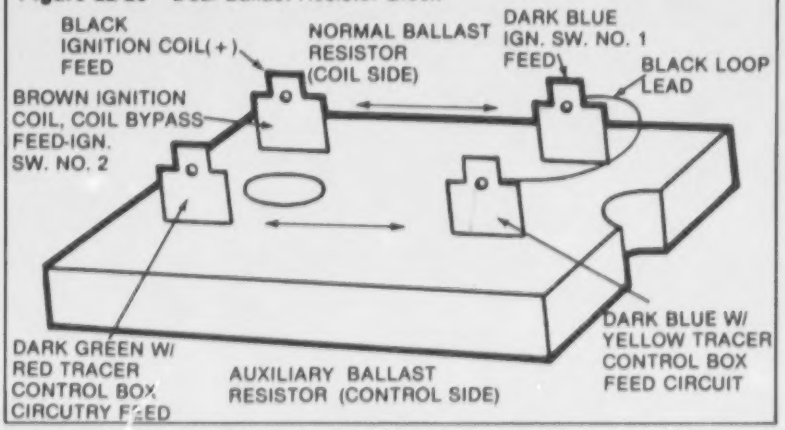
NOTE: The ohmmeter should indicate an open

circuit. If the ohmmeter shows a reading, replace the pickup coil.

Dual ballast resistor tests. To test the Chrysler dual ballast resistor:

- Be sure that the ignition switch is turned off. Then, disconnect all four dual ballast resistor block connector plugs (see figure 22-26).

Figure 22-26 Dual Ballast Resistor Block


BLACK IGNITION COIL(+) FEED
NORMAL BALLAST RESISTOR (COIL SIDE)
DARK BLUE IGN. SW. NO. 1 FEED
BLACK LOOP LEAD
BROWN IGNITION COIL, COIL BYPASS FEED-IGN. SW. NO. 2
DARK BLUE W/ YELLOW TRACER CONTROL BOX FEED CIRCUIT
DARK GREEN W/ RED TRACER CONTROL BOX CIRCUTRY FEED
AUXILIARY BALLAST RESISTOR (CONTROL SIDE)

Adapted from *Sun 2001 Diagnostic Computer, Operator's Manual*, ©1976 Sun Electric Corporation. Used with permission of Sun Electric Corporation.

- With an ohmmeter, test the resistance between the *normal* resistor terminals.

NOTE: The measurement should meet manufacturer's specifications. If you check your technical service manual, these specifications will look like this:

Figure 22-27 Specifications for Coil Side of Ballast Resistor

BALLAST RESISTANCE @ 70-80°F.

Coil Side . . . . . .50-.60 ohms

- Using the ohmmeter, test the resistance between the auxiliary resistor terminals.

NOTE: The measurement should meet manufacturer's specifications. If you check your technical service manual, the specifications will look like this:

Figure 22-28 Specifications for Control Side of Ballast Resistor

BALLAST RESISTANCE @ 70-80° F.

Control side . . . . . 4.75-5.75 ohms

Ignition primary circuit tests. If the engine problem is still there after you've done the distributor air gap adjustment, the pickup coil tests, and the ballast resistor tests, you will have to do a series of primary circuit tests.

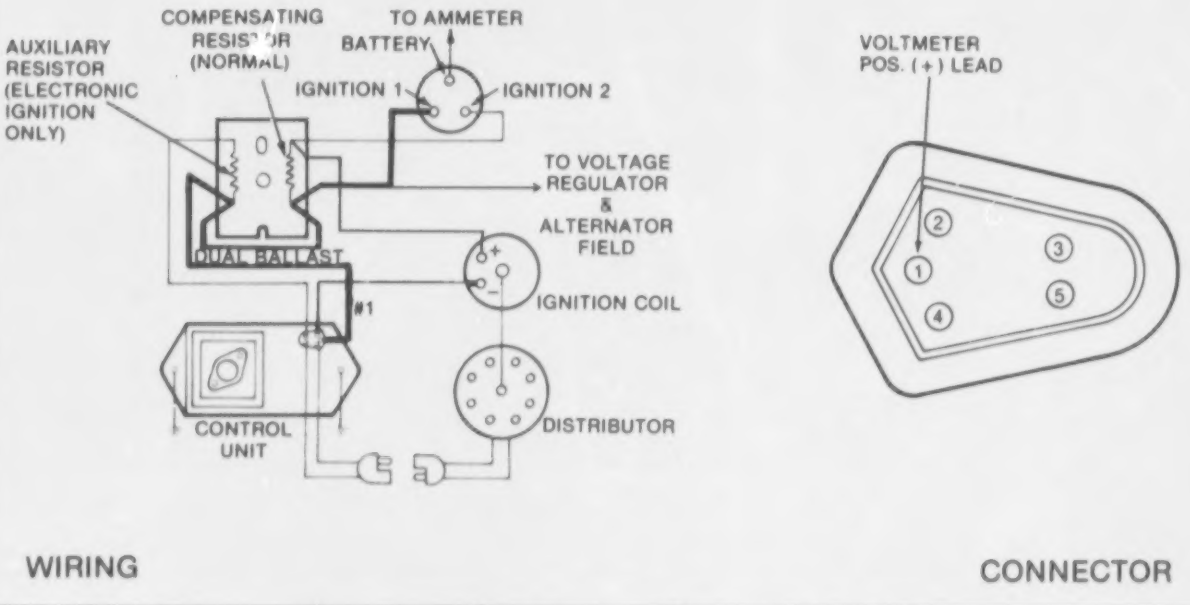
Except for the coil test, these tests are done with a voltmeter. To do the tests, follow the procedures below.

- Turn the ignition switch to off.
- Remove the wiring harness connector from the control unit.

CAUTION: When you remove or install the wiring harness connector, make sure the ignition switch is in the "off" position.

- Turn the ignition switch on and connect the negative lead (–) of the voltmeter to a good ground.
- Connect the voltmeter positive lead (+) to the #1 terminal in the wiring harness connector (see figure 22-29: Connector).

Figure 22-29 Wiring Diagram for Ignition Primary Circuit Tests



Adapted from *Sun 2001 Diagnostic Computer. Operator's Manual.* ©1976 Sun Electric Corporation. Used with permission of Sun Electric Corporation.

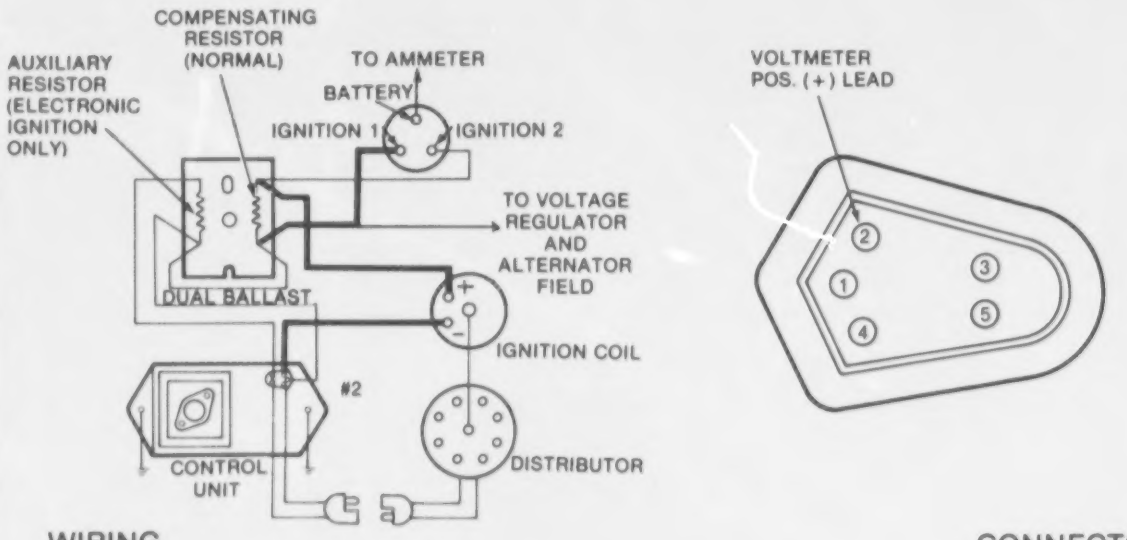
NOTE: The reading should be within one volt of the tested battery voltage (with all accessories turned off).

If the reading is not within these limits, check the following wires (see figure 22-29: Wiring):

- the wire from the #1 connector terminal to the ballast resistor
- the wire from the ballast resistor to the #1 connection on the ignition switch
- the wire from the battery to the ammeter and ignition switch

Connect the voltmeter positive lead (+) to the #2 terminal in the wiring harness connector (see figure 22-30: Connector).

Figure 22-30 Check Wire from the #2 Connector Terminal to Other Components



Adapted from *Sun 2001 Diagnostic Computer. Operator's Manual.* ©1976 Sun Electric Corporation. Used with permission of Sun Electric Corporation.

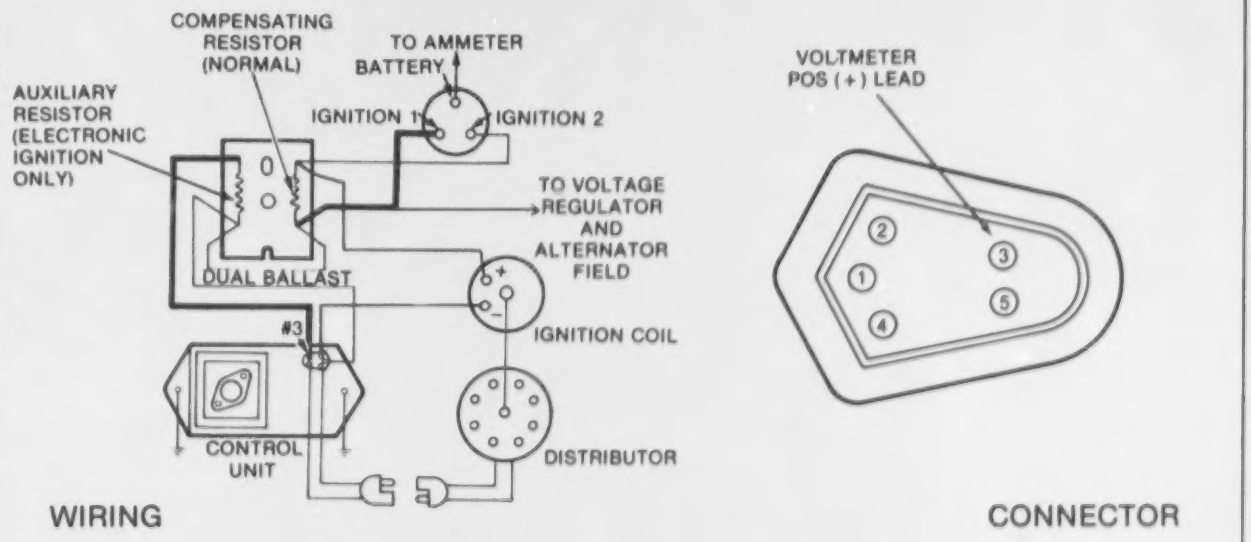
NOTE: The reading should be within one volt of the tested battery voltage (with all accessories turned off). If the reading is not within these limits, check the following wires (see figure 22-30: Wiring):

- the wire from the #2 connector terminal to the negative (−) terminal on the coil
- the wire from the positive (+) terminal on the coil to the ballast resistor

- the wire from the ballast resistor to the #1 connection on the ignition switch
- the wire from the battery to the ammeter and ignition switch

Connect the voltmeter positive lead (+) to the #3 terminal in the wiring harness connector (see figure 22-31: Connector).

Figure 22-31 Check the Wire from the #3 Connector Terminal to Other Components



Adapted from *Sun 2001 Diagnostic Computer, Operator's Manual.* ©1976 Sun Electric Corporation. Used with permission of Sun Electric Corporation.

NOTE: Reading should be within one volt of the tested battery voltage (with all accessories turned off). If the reading is not within these limits, check the following wires (see figure 22-31: Wiring):

- the wire from the #3 connector terminal to the ballast resistor
- the wire from the ballast resistor to the ignition switch
- the wire from the battery to the ammeter and ignition switch

Coil Test

- Visually inspect the ignition coil for a carbonized tower. If the condition is present, replace the coil and the coil secondary lead.

- Test the coil with an ohmmeter to be sure the primary resistance and secondary resistance are correct.
- Refer to your technical service manual for the manufacturer's specifications.

NOTE: Ohms resistance measurements must be within manufacturer's specifications. If they are not, replace the coil.

Control Unit. If all the components tested so far show no defects but the engine malfunction continues, replace the control unit.

The detailed component tests for Chrysler's electronic ignition system are summarized below.

- Check all ignition wiring and connections (secondary wires, coil wire, terminal connections, control connector, distributor lead plug, and ballast resistor).
- Perform the battery voltage test.
- Perform the distributor tests:
  (1) air gap adjustment
  (2) pickup coil tests
- Perform the ballast resistor tests.
- Perform the ignition primary circuit tests (wiring harness connector #1 test, #2 test, and #3 test).
- Perform the coil test.

Turn to your Review Exercise Book and complete Exercise 19.

WORK ACTIVITIES

Before doing a work activity, make sure you've learned all the information that comes before it in the Student Guide. If you need a review, read the information on the pages listed in parentheses next to the work activities. Do not begin any of the work activities until you have your instructor's approval. If you're not sure you can do a work activity, ask your instructor for help.

5. Measure and adjust the Chrysler magnetic distributor air gap (pages 174-175).

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

6. Do the detailed component tests on a Chrysler electronic ignition system. Write down your test results for the following (pages 174-181).

(a) battery voltage test

(b) distributor pickup coil test

(c) dual ballast resistor tests

coil side

control side

(d) ignition primary circuit tests

#1

#2

#3

(e) coil test

primary resistance

secondary resistance

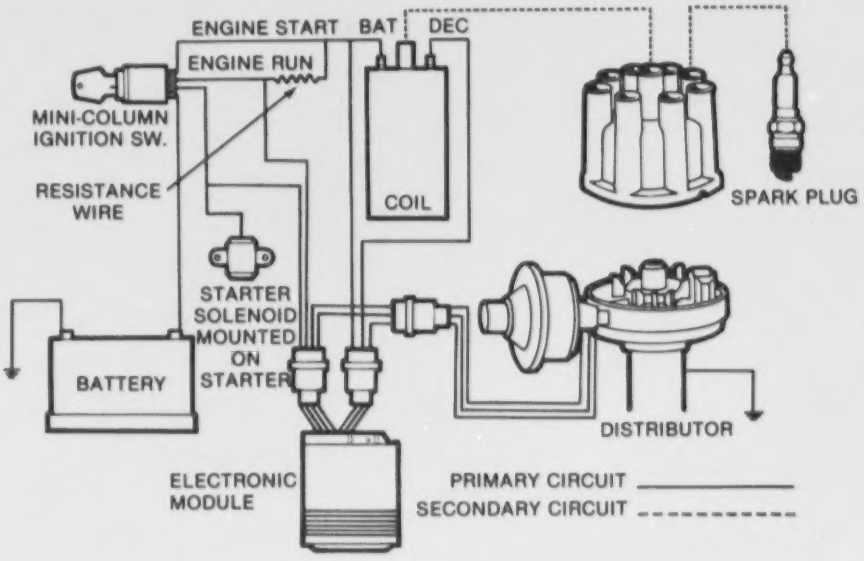
CHECK YOUR WORK WITH YOUR INSTRUCTOR.

After you have finished these work activities, go on to the next section.

Ford Solid-State Ignition System

The Ford ignition system is very similar to the Chrysler electronic system. It consists of a magnetic distributor, and electronic control module, two wire harnesses, a resistance wire, and a special oil-filled coil (see figure 22-32).

Figure 22-32 Ford Solid-State Ignition System



Adapted from *Motorcraft Automotive Ignition Systems*. ©1975 Ford Motor Company. Used with permission of Ford Motor Company.

Notice that the distributor and its operation are also similar to the Chrysler model. As the armature passes the magnetic pickup assembly, it signals the control module to turn the primary current off (see figure 22-33).

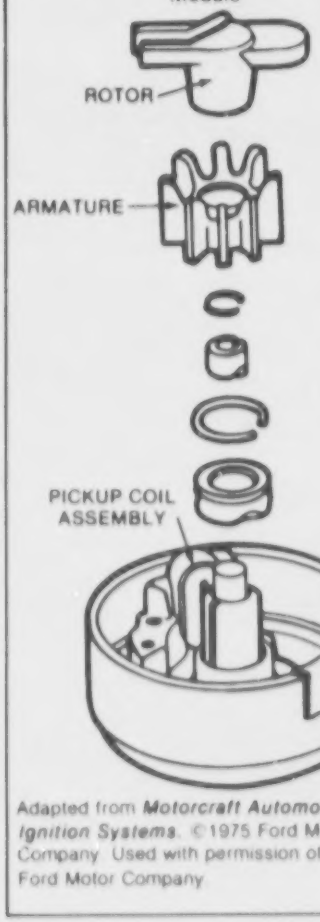
The detailed component tests for the Ford system involve the parts shown in figure 22-33. Remember, you do these tests after you do the initial scope tests and make any necessary repairs. Then, if the ignition system continues to malfunction, do the detailed component tests described below.

These tests are presented in a planned, step-by-step sequence. This means that at any step the ignition problem appears to be corrected, test the vehicle to be sure. If the problem doesn't reappear, you have completed the test procedures. However, if the problem still exists, continue to work through the rest of the test procedures.

Wiring and connections

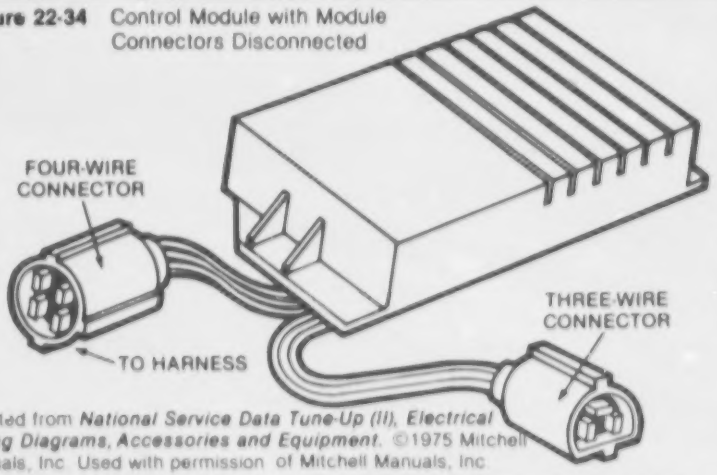
- The first check consists of an inspection of the secondary cables and the primary wires at the coil for looseness. Also look for frayed or broken wires.
- Check the three-way and four-way module connectors and the distributor pigtail connector for tightness and corrosion.

Figure 22-33 Ford Distributor and Control Module



Adapted from *Motorcraft Automotive Ignition Systems*. ©1975 Ford Motor Company. Used with permission of Ford Motor Company.

Figure 22-34 Control Module with Module Connectors Disconnected



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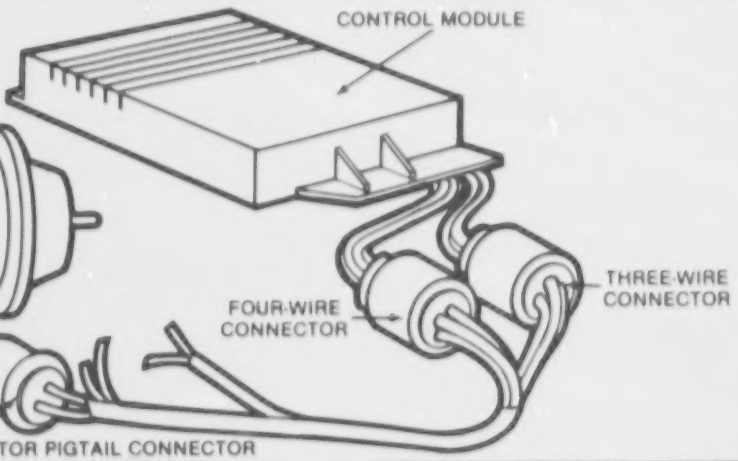


Battery voltage test. Test the battery for acceptable voltages. Proper functioning of the ignition system depends on a battery that has a good charge. Write down the results because you will refer to these test results later as you check out components.

Spark intensity test. Check the secondary ignition circuit.

- Remove the coil high-tension lead from the distributor cap.
- Hold the high-tension lead 3/16 inch from a good ground. Have an assistant crank the engine.

NOTE: If the spark is good, the trouble is in the secondary circuit. If no spark is observed, make sure the high-tension lead is good. If it is good, disconnect the three-wire and the four-wire module connectors (see figure 22-34).

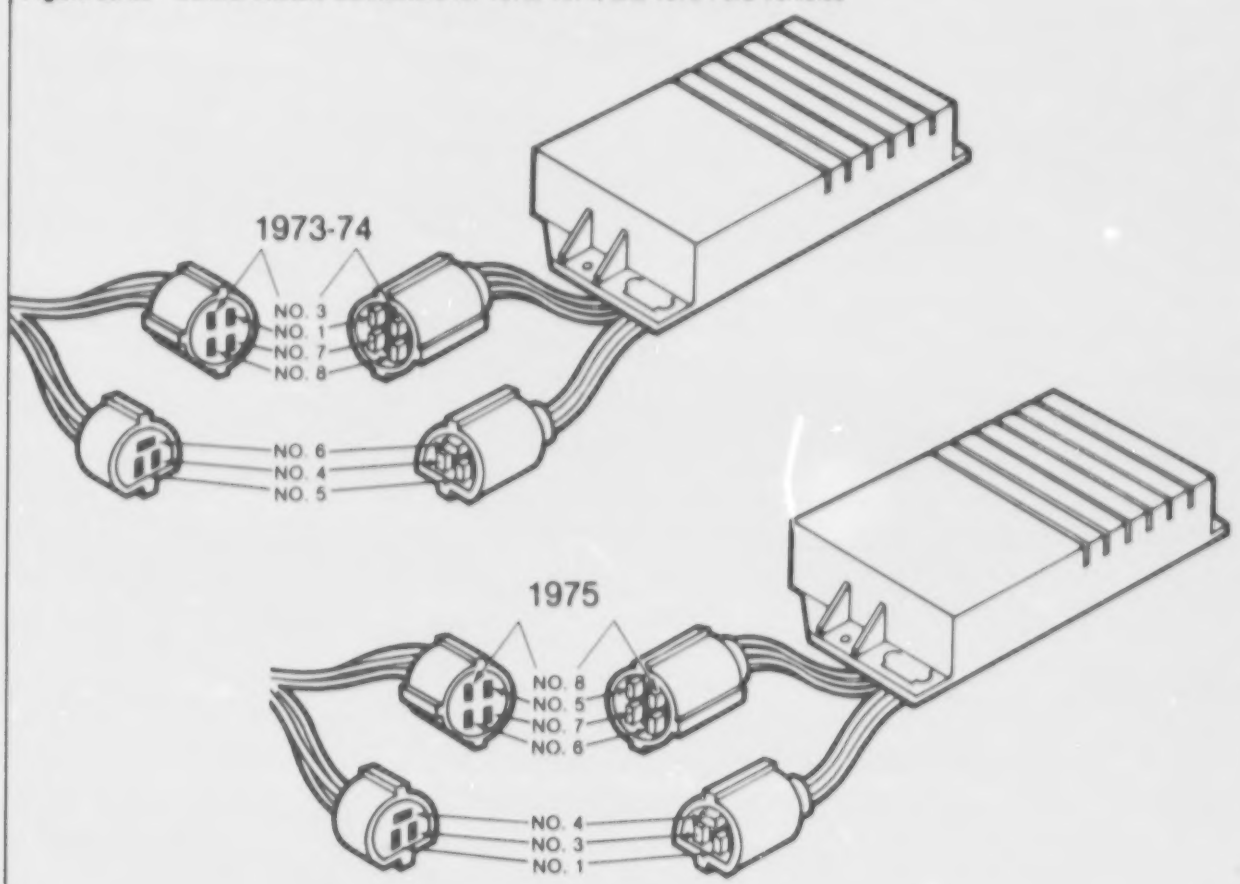
CAUTION: Use only the volt-ohm test procedures as outlined below. ***Do not*** use test equipment that has a knife switch that must be installed on the battery terminal.

Voltmeter tests. These voltmeter tests are done while the ***ignition key is turned on.*** The purpose of the tests is to locate excessive voltage drops, which cause the ignition system to malfunction.

The voltmeter tests that follow are all made at the harness connectors, ***not*** at the module connectors and terminals.

To set up for the tests, attach the NEG (–) voltmeter lead to ground. Connect the POS (+) voltmeter lead to the correct terminal pin location (wire terminal connections) specified in the test procedures.

Figure 22-35 Control Module Connectors for 1973, 1974, and 1975 Ford Vehicles



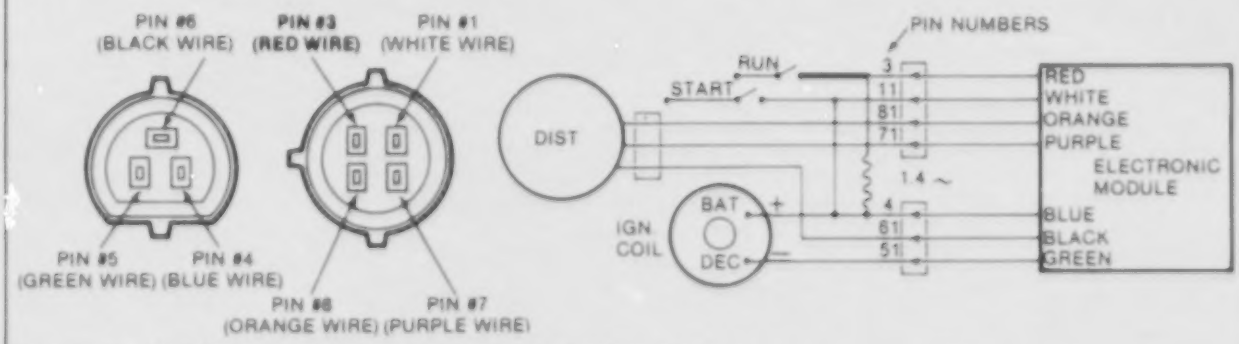
Adapted from ***Motorcraft Automotive Ignition Systems.*** ©1975 Ford Motor Company. Used with permission of Ford Motor Company.

The test procedures covered in this performance objective are for 1973-74 model Ford vehicles. On 1975 models, the tests and test procedures are the same, but the pin locations differ (see figure 22-35). When you test a 1975 model, refer to your technical service manual for the correct terminal pin locations.

Module bias test. This is a test of the voltage available at the module.

- Measure the voltage from pin #3 (red wire) to engine ground (see figure 22-36).

Figure 22-36 Test Connections for Module Bias Test



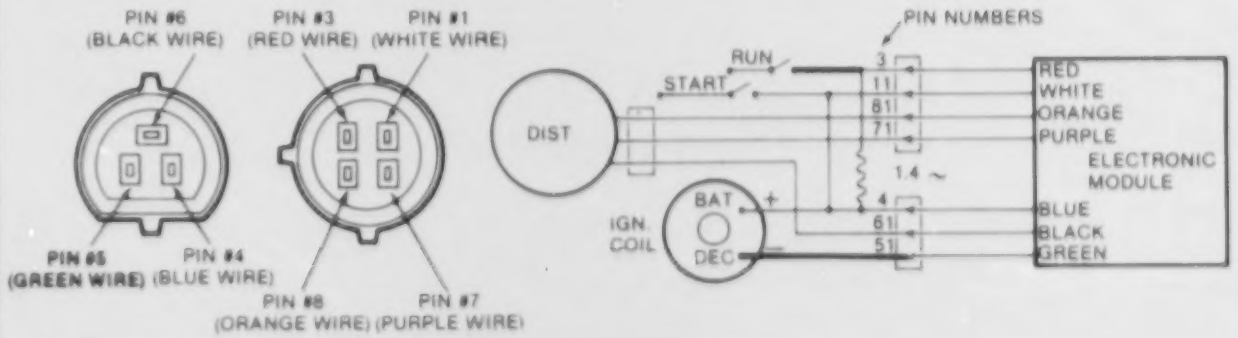
Adapted from *National Service Data Tune-Up (II), Electrical Wiring Diagrams, Accessories and Equipment*. ©1975 Mitchell Manuals, Inc. Used with permission of Mitchell Manuals, Inc.

GOOD The voltage reading should be equal to the tested battery voltage, plus or minus .1 volt.

BAD If the voltage is not within these limits, repair the voltage feed wire to the module (see figure 22-36).

- Test for available voltage at the module from the coil (DEC) terminal. To do this, measure the voltage from pin #5 (green wire) to engine ground (see figure 22-37).

Figure 22-37 Testing for Available Voltage at the Module from the Coil



Adapted from *National Service Data Tune-Up (II), Electrical Wiring Diagrams, Accessories and Equipment*. ©1975 Mitchell Manuals, Inc. Used with permission of Mitchell Manuals, Inc.

GOOD The voltage reading should be equal to the tested battery voltage, plus or minus .1 volt.

BAD If the voltage is not within these limits, do a battery source test.

Battery source test. This is a test of the available voltage at the coil.

- Install a jumper wire from the coil DEC terminal to ground.
- Connect the voltmeter POS (+) lead to the BAT terminal on the coil. Connect the NEG (–) lead to ground.

GOOD The voltmeter reading should be between 4.9 and 7.9 volts.

BAD If the reading is over 7.9 volts, check the ignition resistance wire and replace it if it is defective. You may want to use the ohmmeter to check the resistance reading against the vehicle manufacturer's specifications.

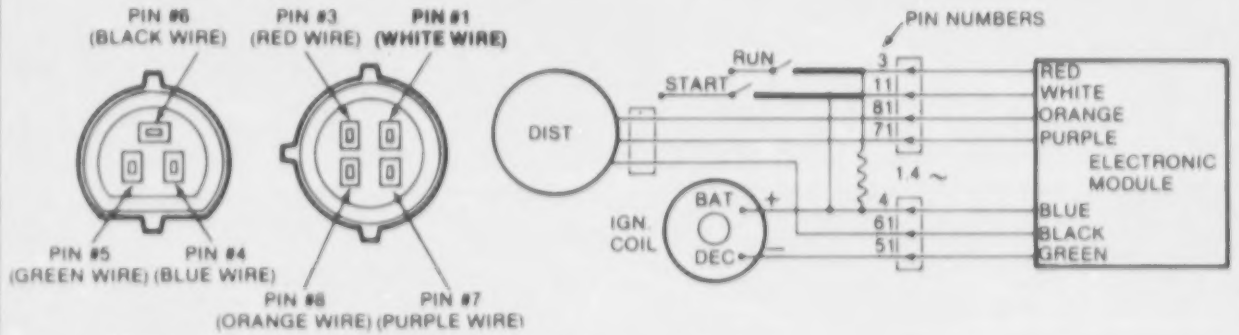
BAD If the reading is less than 4.9 volts, check the primary wiring for worn insulation, frayed or broken strands, and loose or corroded terminals.

The next few tests are made while an assistant cranks the engine.

Cranking test. This is a test of the voltage available at the module during starting.

- While an assistant cranks the engine, measure the voltage from pin #1 (white wire) to engine ground (see figure 22-38).

Figure 22-38 Testing Voltage Available at the Module during Starting



Adapted from *National Service Data Tune-Up (II), Electrical Wiring Diagrams, Accessories and Equipment*. ©1975 Mitchell Manuals, Inc. Used with permission of Mitchell Manuals, Inc.

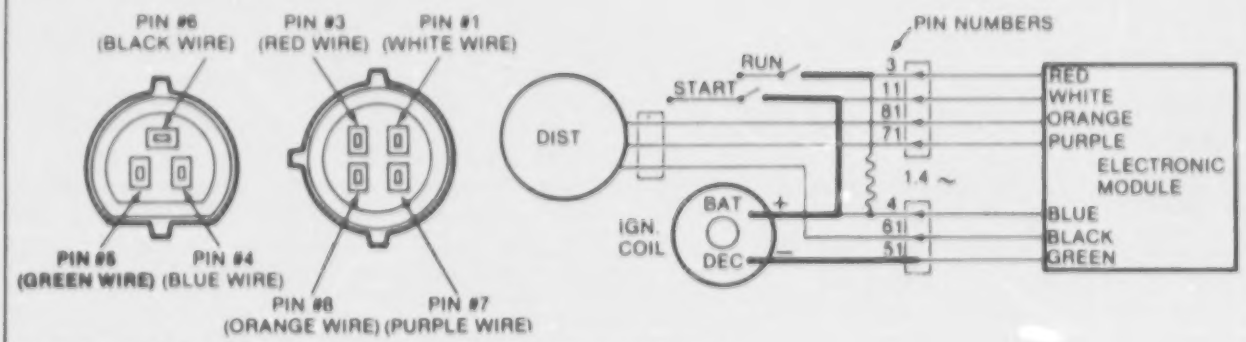
GOOD The reading should be between 8 and 12 volts.

BAD If the voltage reading is less than 8 volts, repair or replace the feed wiring to the module for the ***start*** condition.

Starting circuit test. This is a test of the battery voltage at the module as registered through the ignition bypass circuit.

- While an assistant cranks the engine, measure the voltage from pin #5 (green wire) to engine ground (see figure 22-39).

Figure 22-39 Testing the Starting Circuit



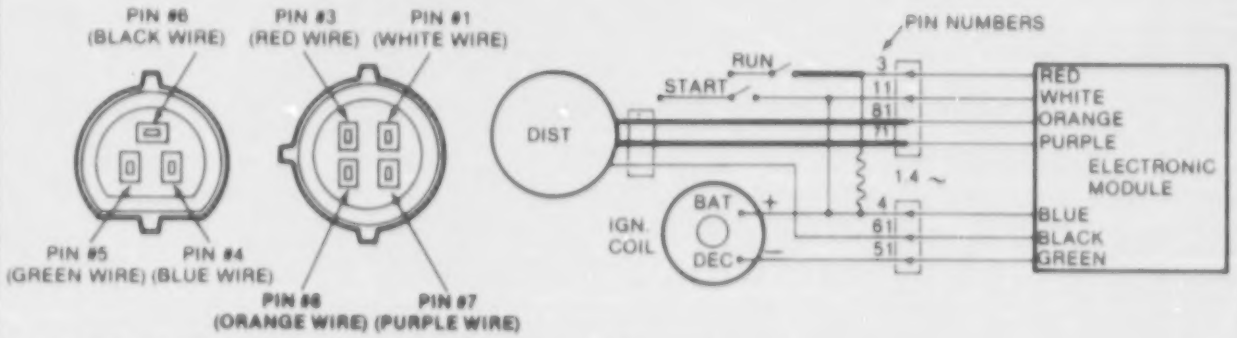
Adapted from *National Service Data Tune-Up (II), Electrical Wiring Diagrams, Accessories and Equipment*. ©1975 Mitchell Manuals, Inc. Used with permission of Mitchell Manuals, Inc.

GOOD The reading should be between 8 and 12 volts.

BAD A voltage reading of less than 8 to 12 volts means that the bypass circuit is open or grounded from either the solenoid or the ignition switch. There may also be a bad connection at the coil primary terminals.

Distributor hardware test. This is a test of the electrical output of the distributor magnetic pickup at the module.

Figure 22-40 Distributor Hardware Test



Adapted from *National Service Data Tune-Up (II), Electrical Wiring Diagrams, Accessories and Equipment*. ©1975 Mitchell Manuals, Inc. Used with permission of Mitchell Manuals, Inc.

- Connect the voltmeter test leads to pin #7 (purple wire) and to pin #8 (orange wire) (see figure 22-40).
- Set the voltmeter on the 2.5 volts scale.
- While an assistant cranks the engine, watch the voltmeter needle and scale.

GOOD Any d.c. volt wiggle. Either the needle will oscillate or the reading will be at least 0.5 volts a.c.

BAD The voltmeter registers no output. This means there is a defect either in the signal generating mechanism or in the harness connection to the module.

NOTE: Ford Motor Company recommends that you remove the distributor cap and check the distributor for visual damage or incorrect assembly. The armature must be tight, not broken, and able to rotate when the engine is cranking. If all internal parts look good, replace the magnetic pickup.

If, after you complete the voltmeter tests, the problem in the ignition system still exists, you should do the

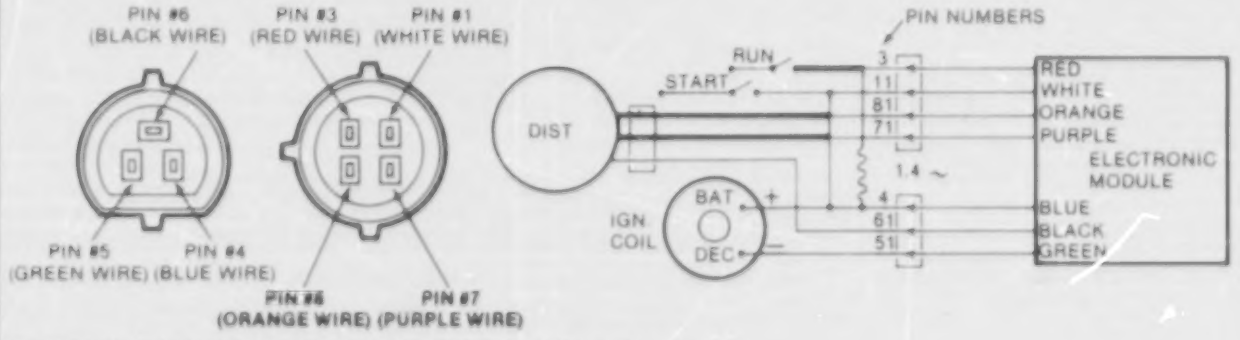
ohmmeter tests described next. These tests also are made at the harness side of the module connectors. And remember, all resistance tests are done with an ohmmeter and with the ignition switch turned off.

Ohmmeter tests. These ohmmeter tests are done while the *ignition key is turned off.*

Magnetic pickup tests. The next four tests measure the internal resistance of the pickup assembly at the module. Follow the sequence as you perform these tests. If you get failing results from a test, stop and replace the magnetic pickup. Once you've found the fault, it is not necessary to continue with the rest of the tests.

- Measure the resistance between pin #7 (purple wire) and pin #8 (orange wire) (see figure 22-41).

Figure 22-41 Magnetic Pickup Test between Pin #7 and Pin #8



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GOOD The ohmmeter reading should be between 400 and 800 ohms.

BAD If the reading is not between 400 to 800 ohms, replace the magnetic pickup assembly.

The voltage tests done with the ignition switch on are summarized in the table below.

Table 22-2 Voltage Tests Performed with the Ignition Switch On

TEST	PROCEDURE	SPECIFICATIONS
1. module bias test	pin #3 and engine ground	battery voltage ± .1 volt
2. battery source test	pin #5 and engine ground	battery voltage ± .1 volt

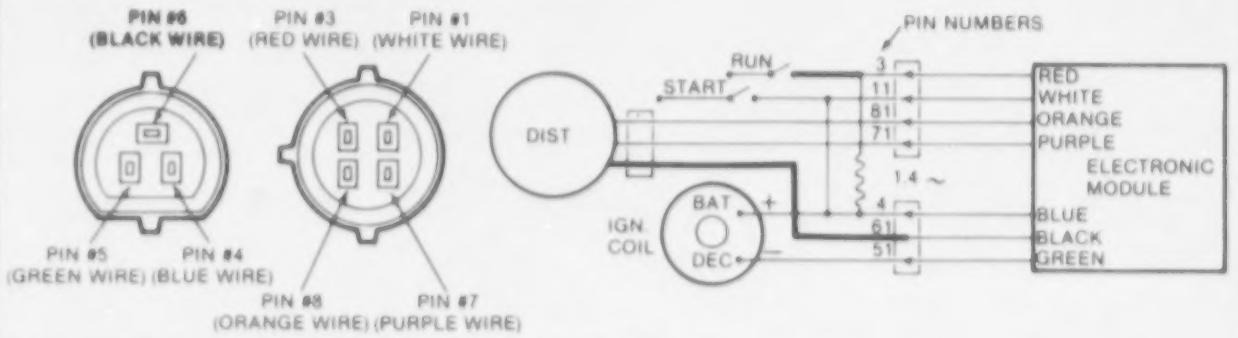
The voltage tests done while the engine is cranking are summarized in the table below.

Table 22-3 Voltage Tests Performed While Engine Is Cranking

1. cranking test	pin #1 and engine ground	8 to 12 volts
2. starting circuit test	pin #5 and engine ground	8 to 12 volts
3. distributor hardware test	pin #7 and pin #8	any d.c. wiggle 1/2 volt min.

- Measure the resistance between pin #6 (black wire) and ground (see figure 22-42). This is a test of ground circuit resistance at the module.

Figure 22-42 Magnetic Pickup Test between Pin #6 and Ground



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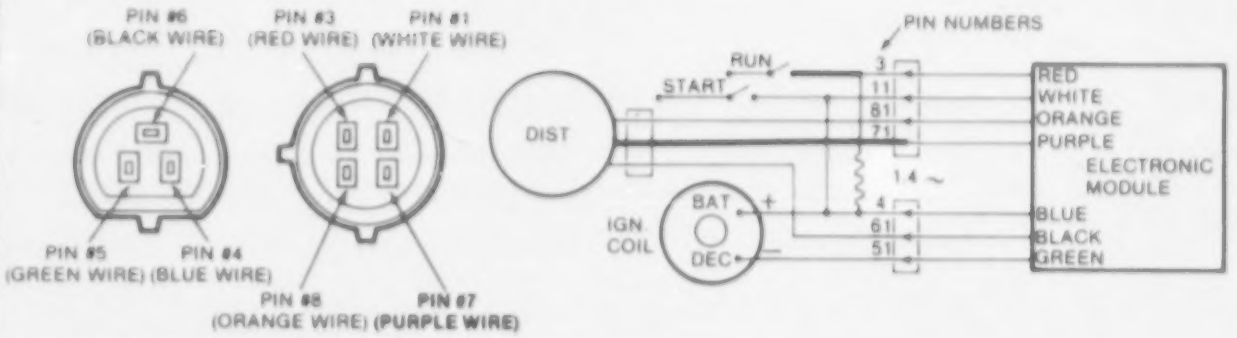
GOOD The ohmmeter reading should be zero.

BAD If the reading is not zero, replace the magnetic pickup assembly.

- Measure the resistance between pin #7 (purple wire) and ground (see figure 22-43).

Figure 22-43 Magnetic Pickup Test between Pin #7 and Ground



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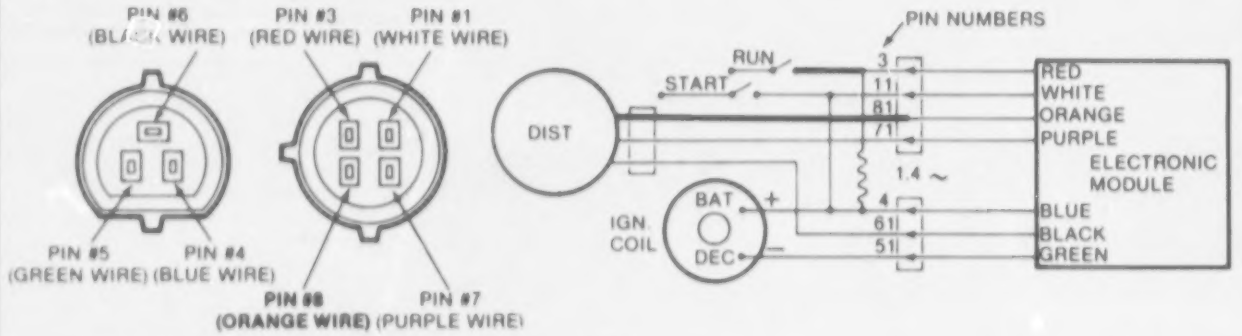
GOOD The ohmmeter reading should be higher than 70,000 ohms.

BAD If the reading is not higher than 70,000 ohms, replace the magnetic pickup assembly.

187

- Measure the resistance between pin #8 (orange wire) and ground (see figure 22-44).

Figure 22-44 Magnetic Pickup Test between Pin #8 and Ground



Adapted from *National Service Data Tune-Up (II), Electrical Wiring Diagrams, Accessories and Equipment*. ©1975 Mitchell Manuals, Inc. Used with permission of Mitchell Manuals, Inc.

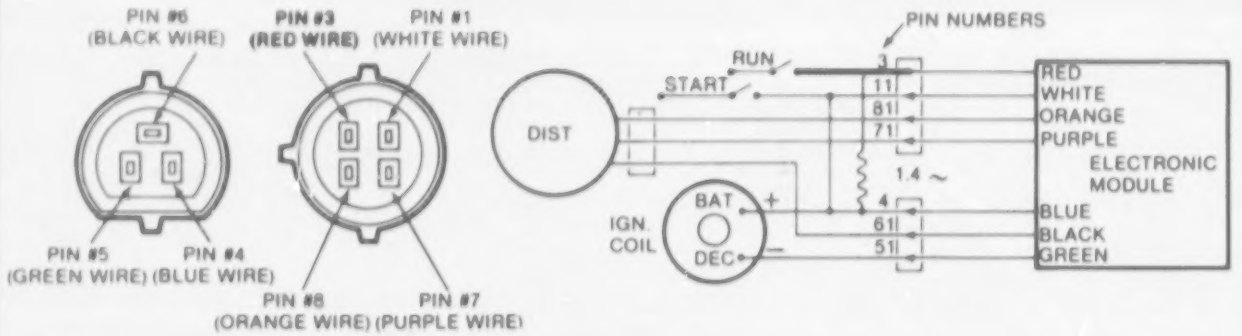
GOOD The ohmmeter reading should be higher than 70,000 ohms.

BAD If the reading is not higher than 70,000 ohms, replace the magnetic pickup assembly.

Ignition coil test. These tests measure resistance in both the coil secondary windings and coil primary windings.

- Secondary windings: measure the resistance between pin #3 and the coil tower (see figure 22-45).

Figure 22-45 Ignition Coil Test



Adapted from *National Service Data Tune-Up (II), Electrical Wiring Diagrams, Accessories and Equipment*. ©1975 Mitchell Manuals, Inc. Used with permission of Mitchell Manuals, Inc.

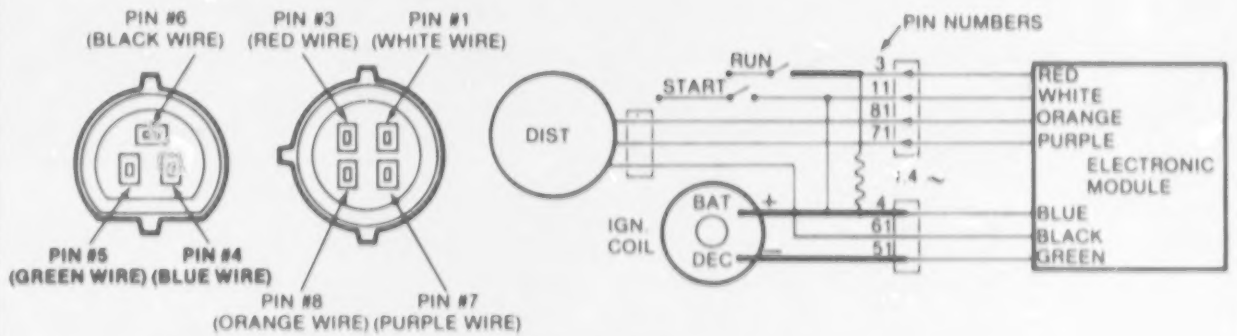
GOOD The ohmmeter reading should be between 7,000 and 13,000 ohms.

BAD If the reading is not between 7,000 and 13,000 ohms, remove the coil and test it on a coil tester. If the coil is defective, replace it.

NOTE: If the test shows that the coil is okay, the problem is in the wiring harness. Repair or replace the harness.

- Primary windings. Measure the resistance between pin #5 (green wire) and pin #4 (blue wire) (see figure 22-46).

Figure 22-46 Test for Primary Windings



Adapted from *National Service Data Tune-Up (II), Electrical Wiring Diagrams, Accessories and Equipment*. ©1975 Mitchell Manuals, Inc. Used with permission of Mitchell Manuals, Inc.

GOOD The ohmmeter reading should be between 1.0 and 2.0 ohms.

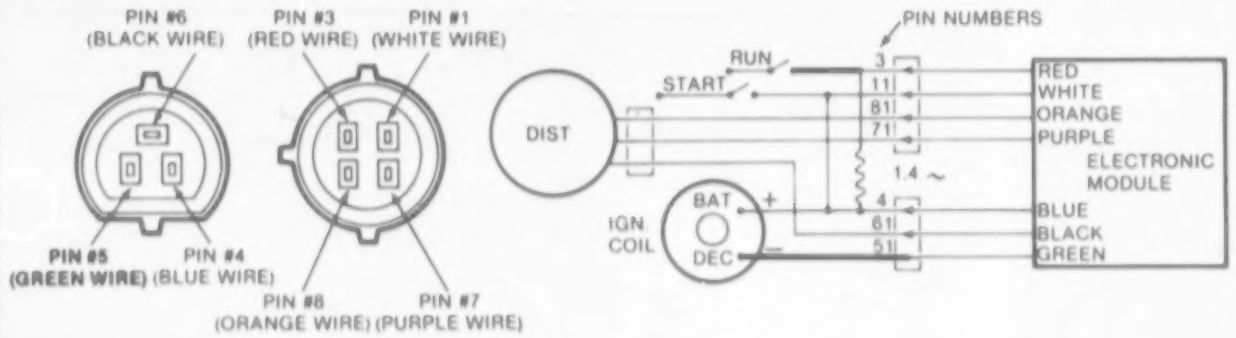
BAD If the reading is not between 1.0 and 2.0 ohms, remove the coil and test it on a coil tester. If the coil is defective, replace it.

NOTE: If the test shows that the coil is okay, the problem is in the wiring harness. Repair or replace the harness.

Test for a short. This is a test to find out if there is a short to ground at the coil DEC terminal or in the primary wiring to the coil.

- Measure the resistance between pin #5 (green wire) and engine ground (see figure 22-47).

Figure 22-47 Test for a Short between the Ground at the Coil DEC Terminal or Primary Wiring of the Coil



Adapted from *National Service Data Tune-Up (II), Electrical Wiring Diagrams, Accessories and Equipment*. ©1975 Mitchell Manuals, Inc. Used with permission of Mitchell Manuals, Inc.

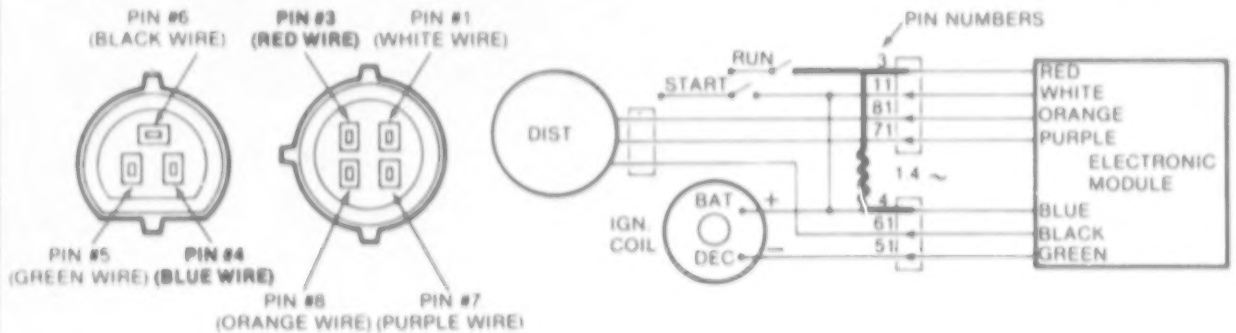
GOOD The ohmmeter reading should be more than 4.0 ohms.

BAD If the reading is not more than 4.0 ohms, check for a short to ground at the DEC terminal of the coil. Also check for a short in the primary wiring to the coil.

Resistance wire test. This is a test of the resistance wire.

- Measure the resistance between pin #3 (red wire) and pin #4 (blue wire) (see figure 22-48).

Figure 22-48 Resistance Wire Test between Pin #3 and Pin #4



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GOOD The ohmmeter reading should be 1.0 to 2.0 ohms.

BAD If the reading is not between 1.0 and 2.0 ohms, replace the resistance wire.

The ohmmeter resistance tests done with the ignition switch off are summarized in Table 22-4.

Table 22-4 Ohmmeter Tests Performed with the Ignition Switch Off

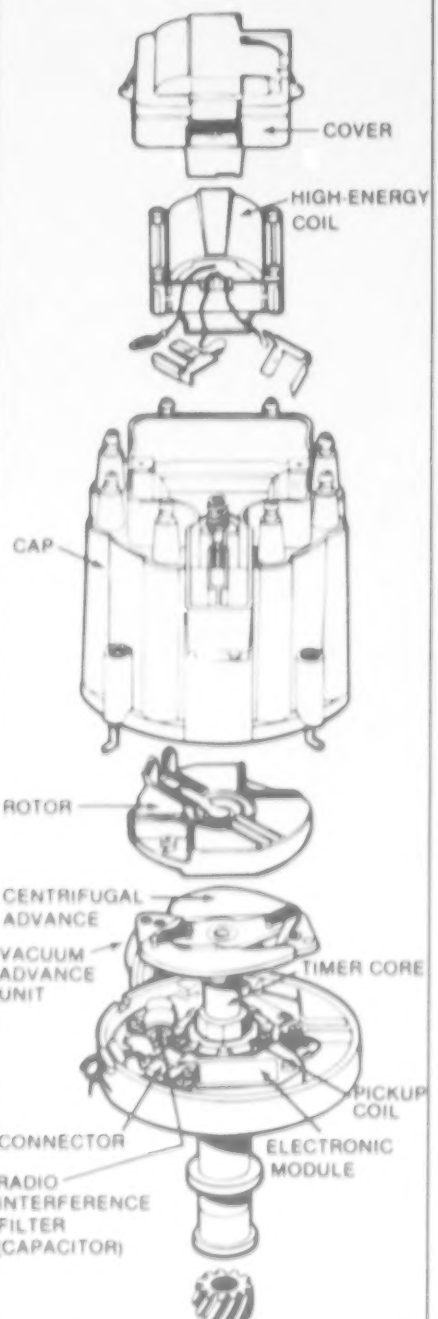
TESTS	PROCEDURE	SPECIFICATIONS
1. magnetic pickup tests	pin #7 and pin #8	400 to 800 ohms
	pin #6 and engine ground	0 ohms
	pin #7 and engine ground	more than 70,000 ohms
	pin #8 and engine ground	more than 70,000 ohms
2. ignition coil tests	pin #3 and coil tower	7,000 to 13,000 ohms
	pin #5 and pin #4	1.0 to 2.0 ohms
3. test for a short	pin #5 and engine ground	more than 4.0 ohms
4. resistance wire test	pin #3 and pin #4	1.0 to 2.0 ohms

If, after you do all the voltage and ohmmeter tests, the ignition problem still exists, plug a module you know is good into the harness connectors. (You don't need to remove the old module or provide a ground for the new one.)

Make a spark intensity test with the good module connected. If the spark is now satisfactory, replace the old module.

Turn to you Review Exercise Book and complete Exercise 20.

Figure 22-49 GM's High-Energy Ignition Distributor



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WORK ACTIVITIES

Before doing a work activity, make sure you've learned all the information that comes before it in the Student Guide. If you need a review, read the information on the pages listed in parentheses after each work activity. Do not begin any of the work activities until you have your instructor's approval. If you're not sure that you can do a work activity, ask your instructor for help.

7. Do all the detailed voltmeter tests for a Ford solid-state ignition system. Write down your test results (pages 185-190).

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

8. Do all the detailed ohmmeter tests for a Ford solid-state ignition system. Write down your test results (pages 190-197).

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

After you have finished these activities, go on to the next section.

General Motors High-Energy Ignition System

Description. In GM's ignition system, the distributor assembly for V-8 and V-6 engines combines all the ignition components into a solid-state electronic unit. This section covers the proper way to do each detailed component test on this ignition system.

Study the distributor shown in figure 22-49, and locate the vacuum and centrifugal advance mechanisms, electronic module, rotor, timer core, pickup coil, distributor cap, ignition coil, and capacitor or radio interference filter for radio noise suppression.

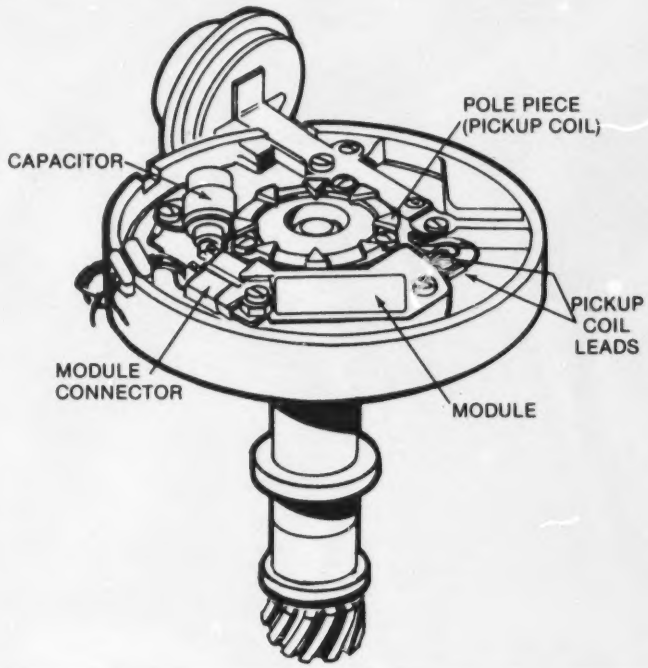
On V-8 and V-6 engines, the distributor cover encloses the ignition coil, which is mounted on the distributor.

On L6 and 4-cylinder engines, however, the ignition coil is not mounted on the distributor. It is mounted separately as in a conventional ignition system. The GM HEI system has no resistor (ballast or resistance wire) or bypass circuit.

Inside the distributor, notice the pickup coil and a circular pole piece with internal teeth (see figure 22-50).

The timer core, with its external teeth, is attached to the distributor shaft.

Figure 22-50 Distributor with Shaft Assembly Removed



The principles of operation are the same for the HEI system as for the other electronic ignition systems. As the teeth of the timer core rotate inside the pole piece and line up with the teeth of the pole piece, a voltage is induced in the pickup coil. This signals the electronic module to open the coil primary circuit. High voltage is then induced in the ignition coil and discharged through the secondary circuit to the spark plugs.

Detailed testing. General cautions during testing procedures on the HEI systems are as follows:

- Do not ground the tachometer terminal of the distributor connector.
- Disconnect the ignition switch connector at the distributor before you make compression checks.
- Whenever you use a timing light, connect the tester lead to the spark plug terminal of the #1 plug. Do not pierce the spark plug wire.

Check the wiring connector to see that it is attached properly at the side of the distributor cap. The connector should be tight and fully inserted.

Check all spark plug wires to be sure they are properly connected at the spark plugs and at the distributor terminals.

Test the battery for acceptable voltages. The proper functioning of the ignition system depends on a battery that has a good state of charge.

Engine will not start. Check the battery voltage at the distributor. To do this, connect the voltmeter POS (+) lead to the BAT terminal lead on the distributor connector, and connect the voltmeter NEG (−) lead to ground.

Turn the ignition switch to On.

GOOD The voltmeter reading is equal to the tested battery voltage ± .1 volt. Do a spark intensity test.

- Remove a spark plug wire. Hold it approximately one-half inch away from the engine block and have an assistant crank the engine for not longer than 30 seconds.
- If a spark occurs, the trouble is not in the ignition distributor. Check the fuel system, spark plugs, and secondary wiring.

BAD If the voltage is zero, repair the open circuit between the BAT terminal and the battery.

- Begin the component testing.
- Turn the ignition switch off.

Component testing: Cap and coil.

There are two test procedures to follow when checking the coil. These are indicated in figures 22-51 and 22-52. To test:

STEP 1 Disconnect the distributor wiring harness connector.

STEP 2 Turn the four cap-to-housing latches and remove the distributor cap and coil assembly. Inspect the rotor, cap, and coil assembly for signs of arc-over. Replace the cap or rotor if needed.

STEP 3 Connect the ohmmeter to the terminals as shown in figure 22-51.

GOOD Reading should be zero or nearly zero.

BAD If reading is not zero or nearly zero, replace the coil.

STEP 4 Connect the ohmmeter to the terminals as shown in figure 22-52. Use the high or middle scale of the meter.

GOOD No reading is registered.
BAD If any reading registers, replace the coil.

Figure 22-51 Ohmmeter Connections for Testing the Coil

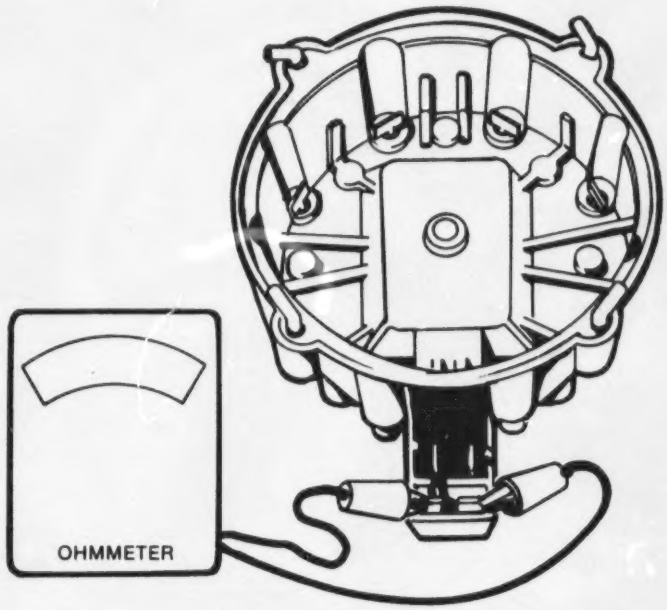
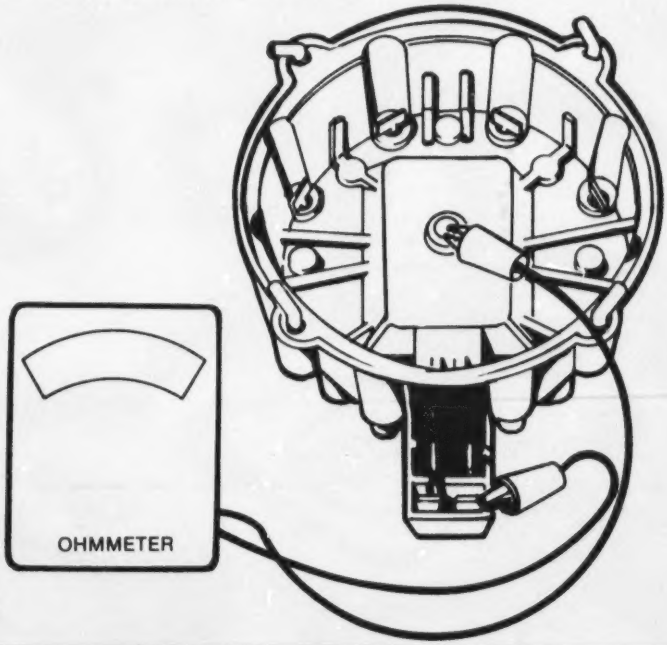


Figure 22-52 Ohmmeter Connections for Testing the Coil



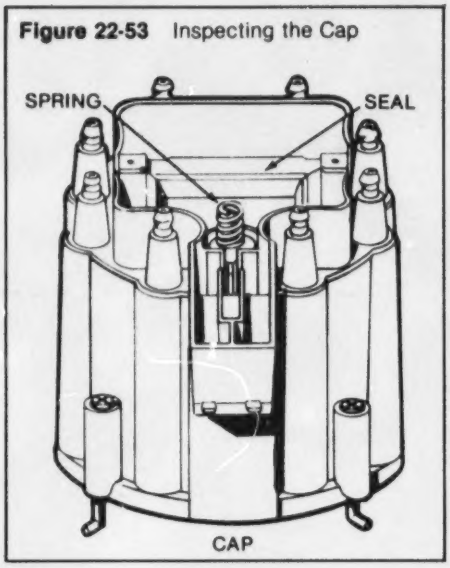


Figure 22-53 Inspecting the Cap

STEP 5 Remove the cover that encloses the coil. Remove the coil itself.

STEP 6 Inspect for arc-over at the spring and seal. If arc-over occurs, replace the cap, coil, or seal as needed.

- If no arc-over occurs, reinstall the coil (see figure 22-53).

Pickup Coil tests

Test #1:

STEP 1 Disconnect the leads going to the pickup coil from the module.

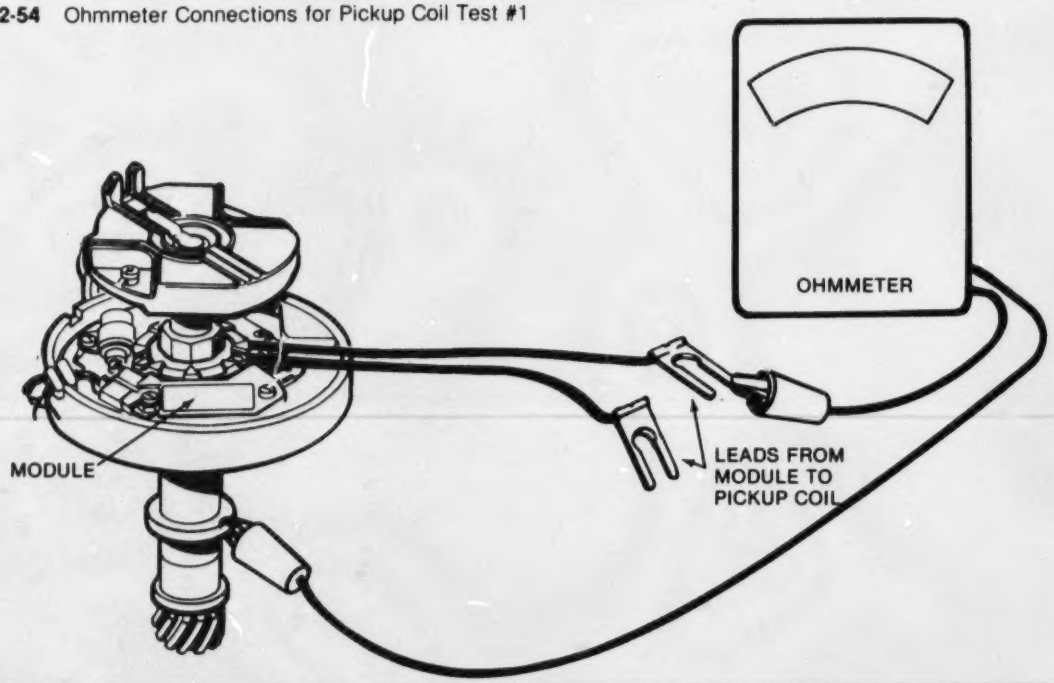
STEP 2 Connect the ohmmeter as shown in figure 22-54.

STEP 3 Connect the test stand vacuum source to the vacuum. Operate the vacuum advance through the vacuum advance range. If the vacuum advance is inoperative, replace the vacuum advance mechanism.

The ohmmeter reading should be infinite (no reading) at all times. If it is not, replace the pickup coil.

If this ohmmeter test indicated a defective coil, it won't be necessary to do test #2.

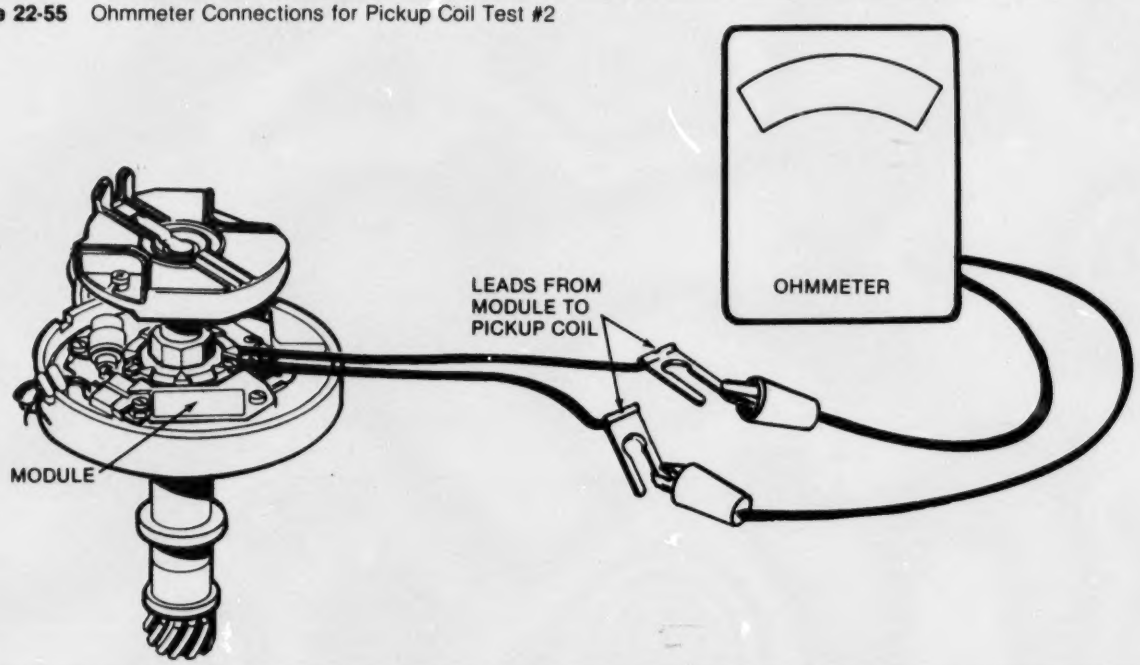
Figure 22-54 Ohmmeter Connections for Pickup Coil Test #1



Test #2:

STEP 1 Connect the ohmmeter as shown in figure 22-55.

Figure 22-55 Ohmmeter Connections for Pickup Coil Test #2



STEP 2 Read the middle scale on the ohmmeter and operate the vacuum advance through the vacuum advance range.

GOOD The ohmmeter should read between 650 and 850 ohms in all vacuum advance positions.

BAD If readings are not between 650 and 850 ohms, replace the pickup coil.

STEP 3 Reinstall the distributor cap and coil assembly. Attach the wiring harness connector to the distributor.

Engine starts but runs rough. If the engine runs rough after you start it, the problem could be any one of several things. First, check your scope test results to be certain you haven't overlooked any defects. Then check for other possible problems, using the items below as a guide.

- Be sure there is proper fuel delivery to the carburetor (fuel pump pressure).
- Check all vacuum hoses. Repair or replace them as needed.

- Watch and listen for sparks jumping to ground.
- Check the initial timing of the engine.
- With the timing light, check the centrifugal timing advance on the engine.
- Remove the spark plugs and check them for common defects such as proper gap, fouling, and cracked insulators.

If the engine continues to run rough after you've checked the scope test results and the items above and made all necessary repairs, you need to do the component tests. Refer to the GM HEI component test procedures.

Electronic module. If, after you complete the previous tests and corrections, the engine operation remains rough, replace the electronic module.

Turn to your Review Exercise Book and complete Exercise 21.

WORK ACTIVITY

Before doing a work activity, make sure you've learned all the information that comes before it in the Student Guide. If you need a review, read the information on the pages listed in parentheses next to the work activity. Do not begin the work activity unless you have your instructor's approval. If you're not sure that you can do the work activity, ask your instructor for help.

9. Do the detailed component tests for a General Motors high-energy ignition system. Record your test results for the following (pages 197-203):

(a) battery voltage
(b) battery voltage at distributor
(c) coil (ohms)
(d) pickup coil (ohms)

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

After you have finished this activity, go on to the next section.

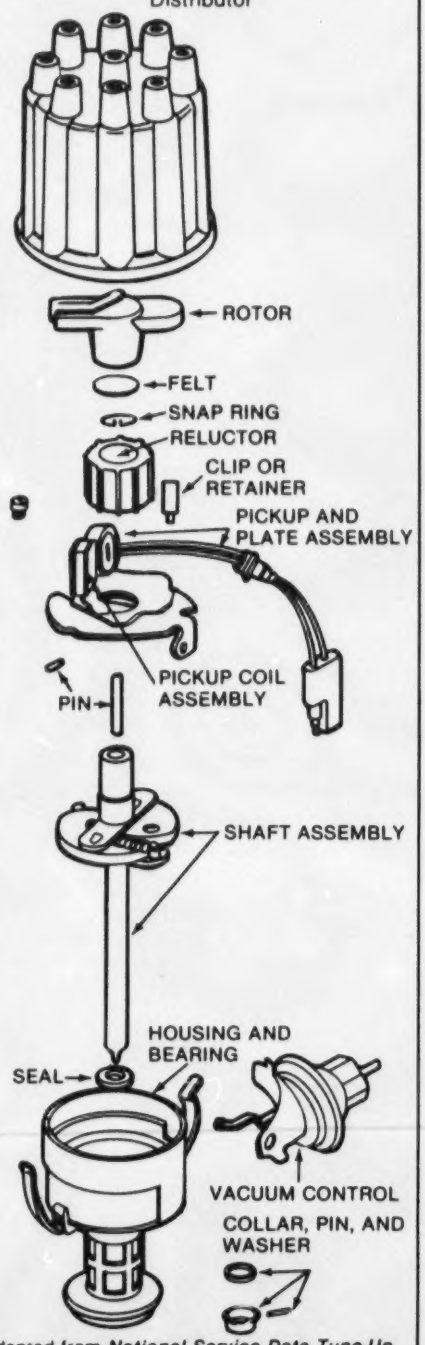


Figure 22-56 Chrysler Electronic Ignition Distributor

Adapted from *National Service Data Tune-Up (II), Electrical Wiring Diagrams, Accessories and Equipment.* ©1975 Mitchell Manuals, Inc. Used with permission of Mitchell Manuals, Inc.

Component Replacement

Electronic distributor services and distributor overhaul procedures are not totally unlike those of conventional distributors. In fact, you may want to review the content of Performance Objective 10, "Remove and Install Distributor;" Performance Objective 11, "Strobe Distributor and Adjust Advance Mechanisms;" and Performance Objective 12, "Overhaul Distributor."

Distributor Removal

The distributor is removed in the conventional way. If you follow the steps given here, you will have no trouble reinstalling the distributor in its correct timing position. Be sure that the engine timing marks are aligned and that the rotor is located on the #1 spark plug wire. Mark the rotor position.

Remove the distributor by pulling it up until the rotor stops turning. Again, mark the position of the rotor.

Distributor Tester

The distributor tester is used on electronic distributors principally for testing, servicing, and adjusting the timing advance mechanisms. To avoid possible injury or damage, always remove the rotor before testing the distributor.

Refer to the vehicle manufacturer's specifications for both the mechanical advance mechanism and the vacuum advance mechanism settings. Test the units through the ranges provided, and make the necessary corrections when they are needed.

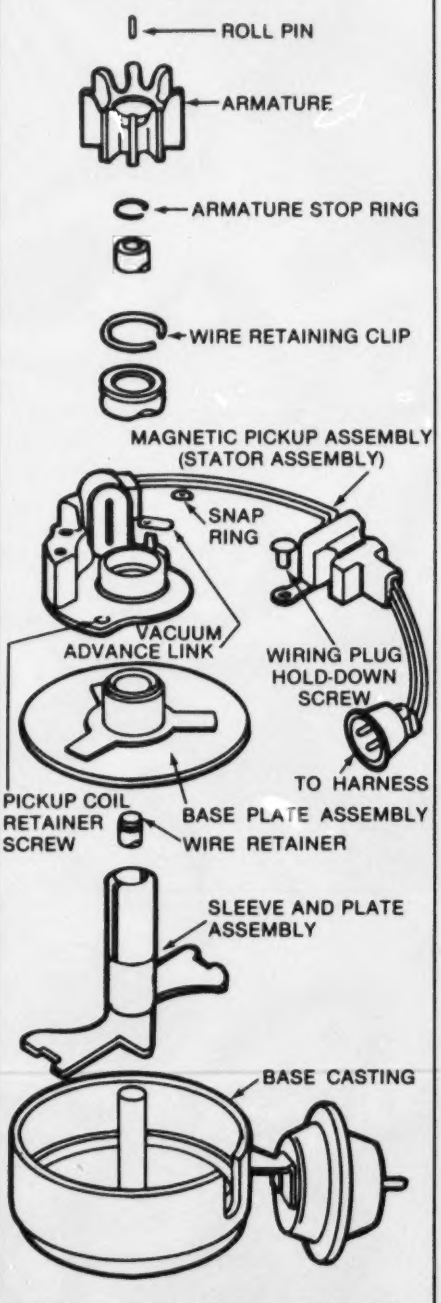
Distributor contact point settings are dwell adjustments, of course, and don't apply to the electronic distributor. However, you'll recall that you can adjust the air gap between the reluctor tooth and the stationary pole piece on the Chrysler electronic distributor. This air gap can be adjusted while the distributor is on the distributor tester.

Pickup Coil Replacement

As part of the detailed component testing procedures described in this performance objective, you may be required to replace the pickup coil assemblies in the various electronic distributors. This section covers step-by-step procedures for each distributor system.

- Remove the distributor cap. Remove the rotor and the felt pad from the top of the distributor (see figure 22-56).
- Remove the snap ring from the top of the reluctor.
- Remove the reluctor. If the reluctor cannot be pulled off easily, use two screwdrivers (7/16-inch

Figure 22-57 Ford Solid-State Electronic Distributor



Adapted from *National Service Data Tune-Up (II), Electrical Wiring Diagrams, Accessories and Equipment.* ©1975 Mitchell Manuals, Inc. Used with permission of Mitchell Manuals, Inc.

blades) and pry up from the bottom of the reluctor.

CAUTION: Be extremely careful not to damage the teeth on the reluctor.

- Remove the vacuum control from the side of the distributor housing.
- Remove the pickup coil and the upper plate by pushing down on the retainer clip and moving the upper plate away from the mounting stud. The pickup coil cannot be removed from the upper plate.
- Install the new pickup assembly by reversing the order of the removal procedures.
- Adjust the air gap on the installed assembly, following the vehicle manufacturer's requirements. Refer to the adjustment procedures given in this performance objective.
- Remove the distributor cap and rotor (see figure 22-57).
- Disconnect the distributor harness connector at the distributor. Remove the armature from the distributor shaft.

NOTE: Use a smaller gear puller or two screwdrivers to lift or pry the armature off the distributor shaft.

- Remove the roll pin and the wire retaining clip.
- Remove the snap ring that secures the vacuum advance link to the pickup assembly.
- Remove the pickup coil assembly retaining screws and lift the assembly from the distributor.
- Install the new pickup assembly by reversing the order of the removal procedures.

To remove:

- Remove the distributor from the vehicle (see figure 22-58).
- Remove the rotor. Disconnect the pickup coil leads from the electronic module terminals.
- Remove the roll pin from the drive gear by driving it out with a punch. Be sure the distributor is properly supported when you drive the roll pin out.
- Remove the drive gear, shim, and tanged or wave washer (similar to those on conventional distributors). File away any burrs that may have been caused by removal of the pin.

Figure 22-58 GM High-Energy Ignition System

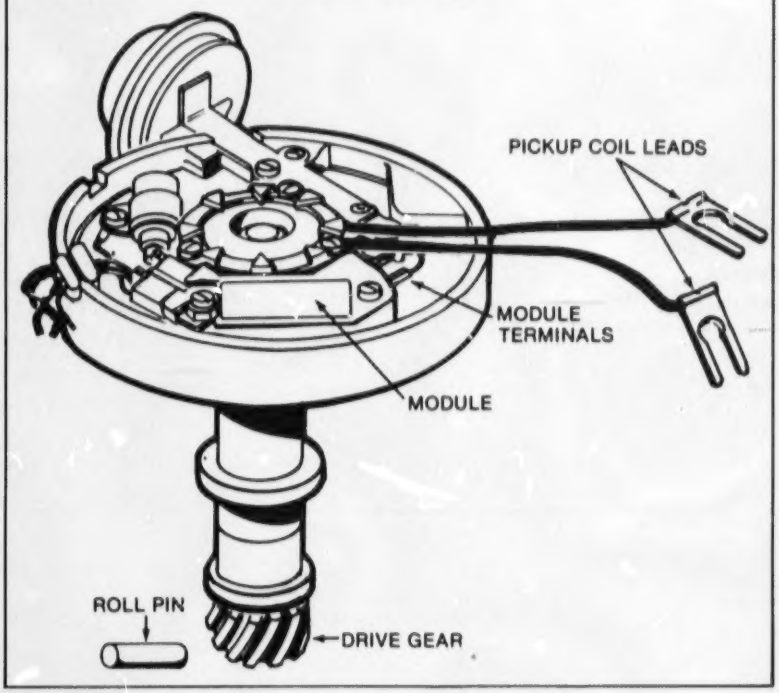
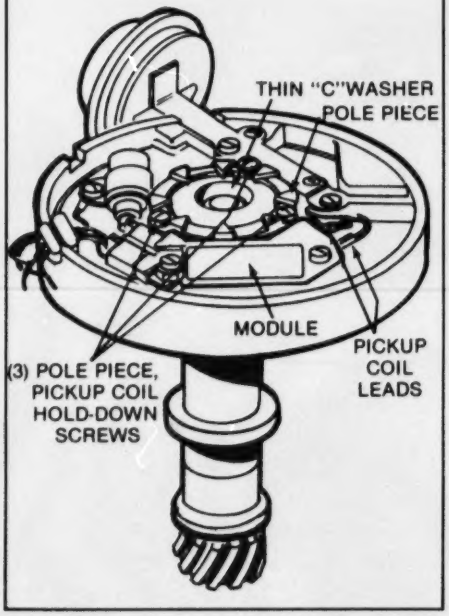


Figure 22-59 Distributor with Shaft Removed

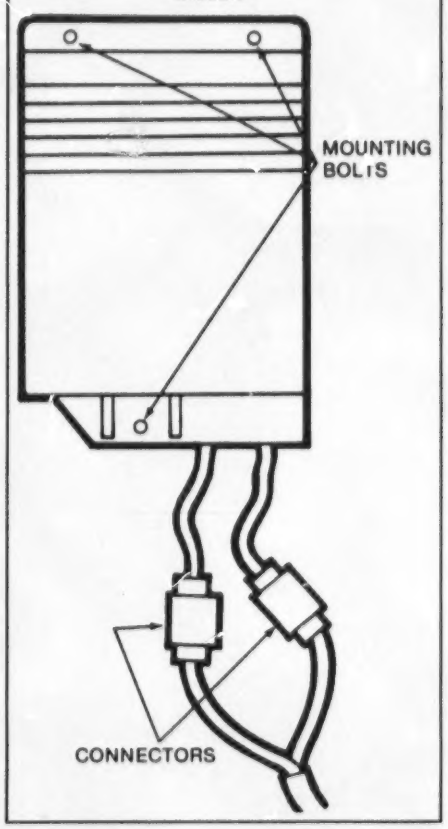


- Remove the distributor shaft from the housing. The mechanical advance mechanism and the timer core are attached to the shaft.
- Remove the thin "c" washer from the upper end of the distributor housing (see figure 22-59).
- Remove the three screws that hold the pole piece to the distributor housing. Remove the pole piece, magnet, and pickup coil.

To install:

- Install pickup coil, magnet, and pole piece. Install the three hold-down screws, but leave them loosely attached at this time.
- Install the thin washer at the top of the housing. Install the distributor shaft and rotate it to check for proper clearance between the pole-piece teeth and the timer-core teeth (see figure 22-59).
- If necessary, realign the pole piece to center it to the timer core. Be sure there is adequate and equal clearance between the two units when the timer core is rotated. Now tighten the three pole piece hold-down screws.

Figure 22-60 Ford Electronic Control Module



- Install the tanged washer, shim, and drive gear. Align the hole in the drive gear with the hole in the distributor shaft. Then install a new roll pin and peen it to lock it in place (see figure 22-58).

Module Replacement

The electronic modules on both the Chrysler electronic ignition system and the Ford solid-state ignition system are separate units, mounted apart from the distributor (see figure 22-60).

To replace (see figure 22-60 for both the Ford and Chrysler systems):

- Disconnect the ignition wiring harness connector(s).
- Remove the module mounting bolts and remove the module from the vehicle.
- *To install:* Install the module by reversing the removal procedures. After you have installed the module, make an operational check of the engine to be sure it operates properly.
- ***To replace GM high-energy ignition (see figure 22-61):***
- Disconnect the wiring harness at the side of the distributor cap.
- Remove the distributor cap.
- Remove the rotor.
- Disconnect the module connector and the pickup coil leads from the module terminals.
- Remove the two mounting screws and remove the module from the distributor.

To install the new GM module (see figure 22-60):

- Coat the bottom of the new module with the dielectric lubricant that comes with the new module. This lubricant helps to transfer heat to the distributor housing.
- Install the module by reversing the removal procedure.

Ignition Coil Replacement

For the Chrysler electronic ignition system, the Ford solid-state ignition system, and the GM high-energy ignition system for L6 and 4-cylinder engines, the ignition coils are separate units mounted apart from the distributor.

Figure 22-61 GM Electronic Module inside the Distributor

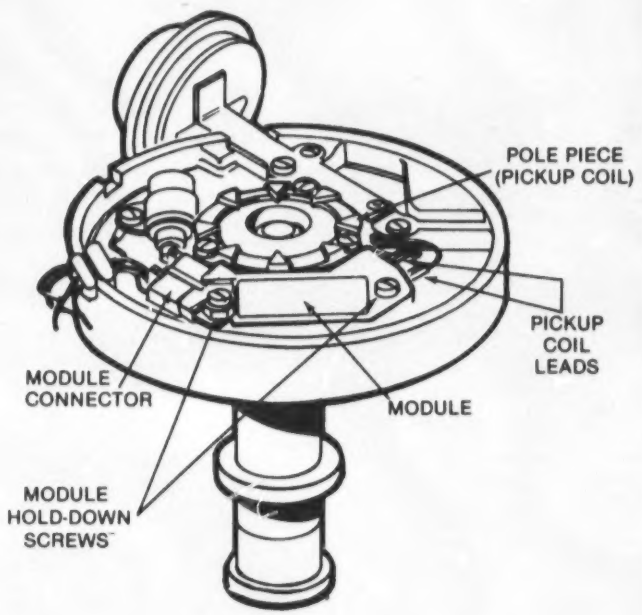
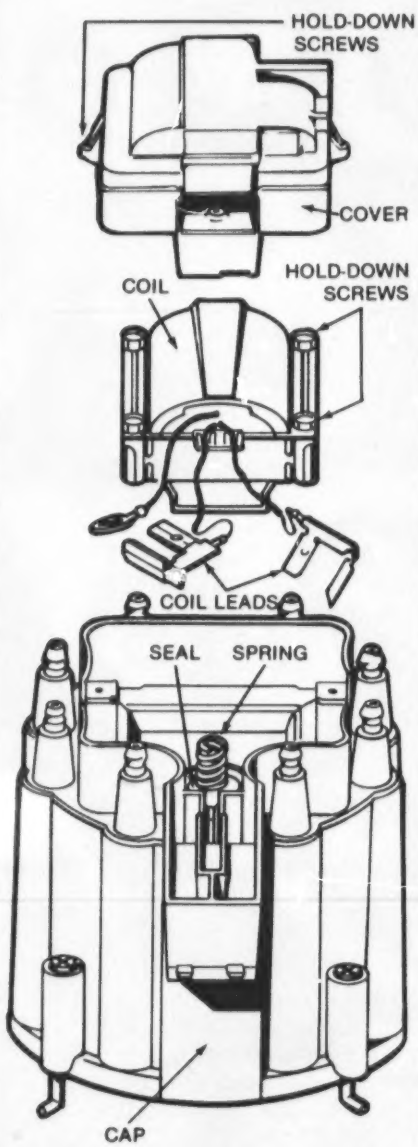


Figure 22-62 GM Distributor Cap



To replace the coils on Chrysler and Ford modules:

- Remove the coil high-tension lead from the center of the coil.
- Disconnect the primary BAT(+) lead and the DIST or DEC (−) lead from the coil terminals. On the GM L6 and 4-cylinder engines, disconnect the primary ignition lead connector.
- Remove the ignition coil mounting bolts, and remove the coil from the vehicle.

To install:

- Reverse the removal procedures.

To replace the coil on GM high-energy V-8 and V-6 ignition system (see figure 22-62):

- Remove the screws holding the cover (coil) to the distributor cap. Remove the cover.
- Remove the four screws holding the coil to the distributor cap.

- Disconnect the harness connector and the battery wire from the side of the distributor cap.
- Push the coil leads out of position in the distributor cap. Remove the coil.
- *To install:* Install the ignition coil by reversing the removal procedures.

Distributor Overhaul

Once you've learned how to replace the components in these electronic distributors, you should have no problem overhauling them, since the procedure is much the same as overhauling conventional distributors. The same precautions and the same requirement that all moving parts be lubricated upon reassembly apply.

Remember, the GM high-energy ignition distributor does not allow servicing or replacement of the distributor shaft bushings. Therefore, if the bushings and shafts are worn, the entire distributor housing must be replaced. For other distributor models, you can replace the bushings and hone them to fit, as you did for conventional distributors.

Turn to your Review Exercise Book and complete Exercise 22.

WORK ACTIVITIES

Before doing a work activity, make sure you've learned all the information that comes before it in the Student Guide. If you need a review, read the information on the pages listed in parentheses next to the work activities. Do not begin any of the work activities until you have your instructor's approval. If you're not sure you can do a work activity, ask your instructor for help.

10. Remove and install the pickup coil assembly of a Chrysler or Ford transistor distributor (pages 204-208).

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

11. Remove and install the pickup coil assembly of a General Motors high-energy ignition distributor (pages 205-208).

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

12. Remove and install the electronic module of a Chrysler or Ford transistor ignition system (pages 207-208).

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

13. Remove and install the electronic module of a General Motors high-energy ignition distributor (pages 207-208).

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

14. Remove and install the ignition coil of a General Motors high-energy ignition distributor (pages 207-208).

CHECK YOUR WORK WITH YOUR INSTRUCTOR.

When you have finished these activities, ask your instructor to return your pretest on Performance Objective 22. Complete the questions that you missed or were unable to answer the first time you took the pretest. Check your answers with your instructor when you finish. Your instructor will tell you if you are ready to be checked off on the performance checklist, or if you need to correct some of your answers first.

If you are told by your instructor that you are ready for the performance checklist, carefully tear the checklist out of your Review Exercise Book and give it to your instructor. After you have been satisfactorily checked off on the checklist, ask your instructor for the posttest for Unit 4.